G.E.C. JOURNAL

VOLUME 24 Number 1 JANUARY 1957

THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND

Volume 24, number 1

JANUARY, 1957

G.E.C. JOURNAL

CONTENTS

Page

2 Frontispiece—The diesel-electric Royal Research Ship "John Biscoe"

PROGRESS 1956

3 Atomic Power

6 Heavy Engineering and Plant

22 Power Distribution and Control

29 Instrumentation

33 Transport

40 Lamps and Lighting

52 Telecommunications

63 Heating and Ventilation Engineering

70 Research

80 Technical Literature

COVER PICTURE

A general view of the King George V Dock at Hull, where an extensive electrification scheme has been carried out.

Published by
THE GENERAL ELECTRIC CO. LTD.
Magnet House, Kingsway, London, W.C.2

Copyright

Printed by The Hollen Street Press, Ltd., London, W.1

The diesel-electric Royal Research Ship "John Biscoe", of the Falkland Islands Dependencies Survey, leaving Southampton on Antarctic survey service.

Atomic Power

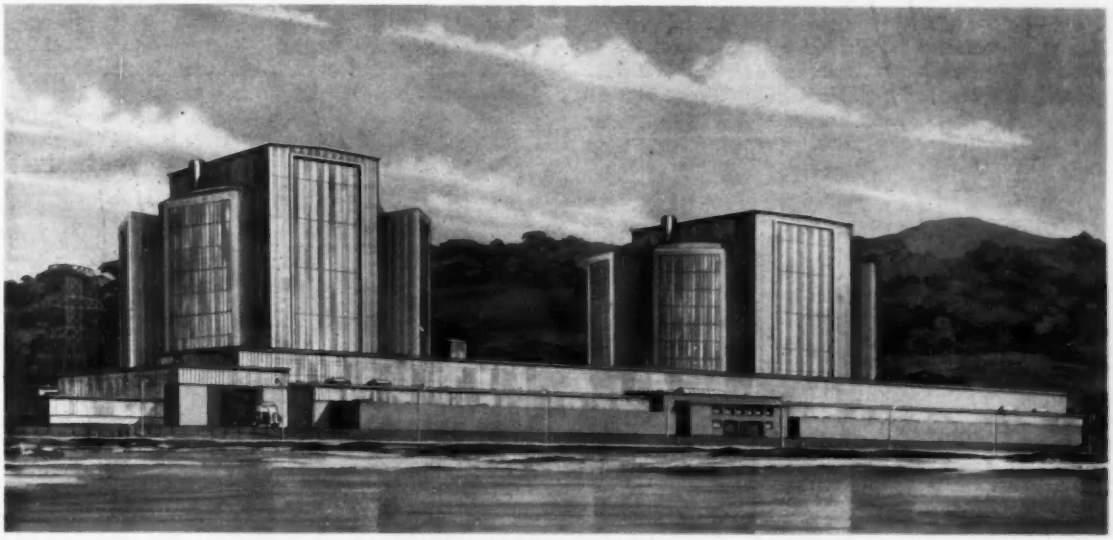


Fig. 1.—An impression of the complete nuclear power station to be built by the G.E.C.—Simon-Carves Atomic Energy Group for the South of Scotland Electricity Board.

WORLD'S LARGEST NUCLEAR POWER STATION.

The placing of a contract with the G.E.C. by the South of Scotland Electricity Board for building the world's largest atomic power station was announced on December 15.

Power will be derived from the heat generated by a controlled nuclear fission chain reaction in two nuclear reactors (fig. 1). The principle of operation will be similar to that of the Calder Hall reactors in that the natural uranium fuel will be contained within a pile of graphite moderator material and the heat extracted by circulating carbon dioxide gas under pressure.

The generating capacity of the station will be 360,000 kilowatts and the total output of electrical power is guaranteed to be not less than 300,000 kilowatts, rising to 320,000 kilowatts, all of which will be fed into the National Grid. Furthermore, the station has been designed to operate on base load, so that every day between 5 and 6 million units of electricity will be sent out to consumers. The saving in coal from this one station will amount to at least 1 million tons a year.

Each reactor with its eight steam raising units will weigh about 70,000 tons, the entire structures being supported on thick concrete rafts.

The erection programme will be greatly assisted by a specially built Goliath crane—the largest in the world. Its 200 ft. span, the same as the centre span of London's Tower Bridge, will enable it to straddle the construction site, and it will be capable of lifting up to 300 tons at a time.

Associated with the G.E.C. and Simon-Carves Ltd. in this great enterprise are The Motherwell Bridge and Engineering Co. Ltd., who will fabricate the pressure vessels, and John Mowlem (Scotland) Ltd., who will be the civil contractors.

REACTOR CORE.

The cylindrical core of each reactor, 28 ft. high and 50 ft. in diameter, is built up of 2,000 tons of graphite blocks containing vertical channels for the fuel elements and control rods (fig. 2).

Each of the 3,288 fuel channels contains 10 individual fuel elements stacked in a column one on top of the other. The element consists of a bar of natural uranium

metal sealed in a magnesium alloy can which is finned to assist heat extraction.

The total charge of uranium in the two reactors is 500 tons.

There is a limit to the amount of heat which can be extracted from a fuel element. This limit is set by the heat transfer characteristics of the canning material, and by the flow of coolant. In order to increase the total heat output of the reactor without overheating the central channels, the neutron flux distribution (which directly governs the local heat output) is flattened so that as many channels as possible run at the maximum heat rating.

The flattening is carried out by inserting neutron-absorbing stainless steel rods into a number of the central core channels ; the flattening rods provide an artificial wastage of neutrons equal to the geometrical leakage in the outer portion of the core. As the fuel is burned up during operation the absorbing material is gradually removed and the flattening is finally achieved by using depleted uranium in the centre of the core. In this way a higher burn-up of the central fuel elements is attained.

Pressure Vessels.

The reactor core rests on a grid made of steel plates arranged in " egg-box " fashion. Surrounding the sides and top of the core is an inner steel shell made of relatively thin steel plate.

A 70 ft. diameter spherical pressure vessel, welded from 3 in. thick steel plate and weighing nearly 1,000 tons, completely encloses the core and inner shell.

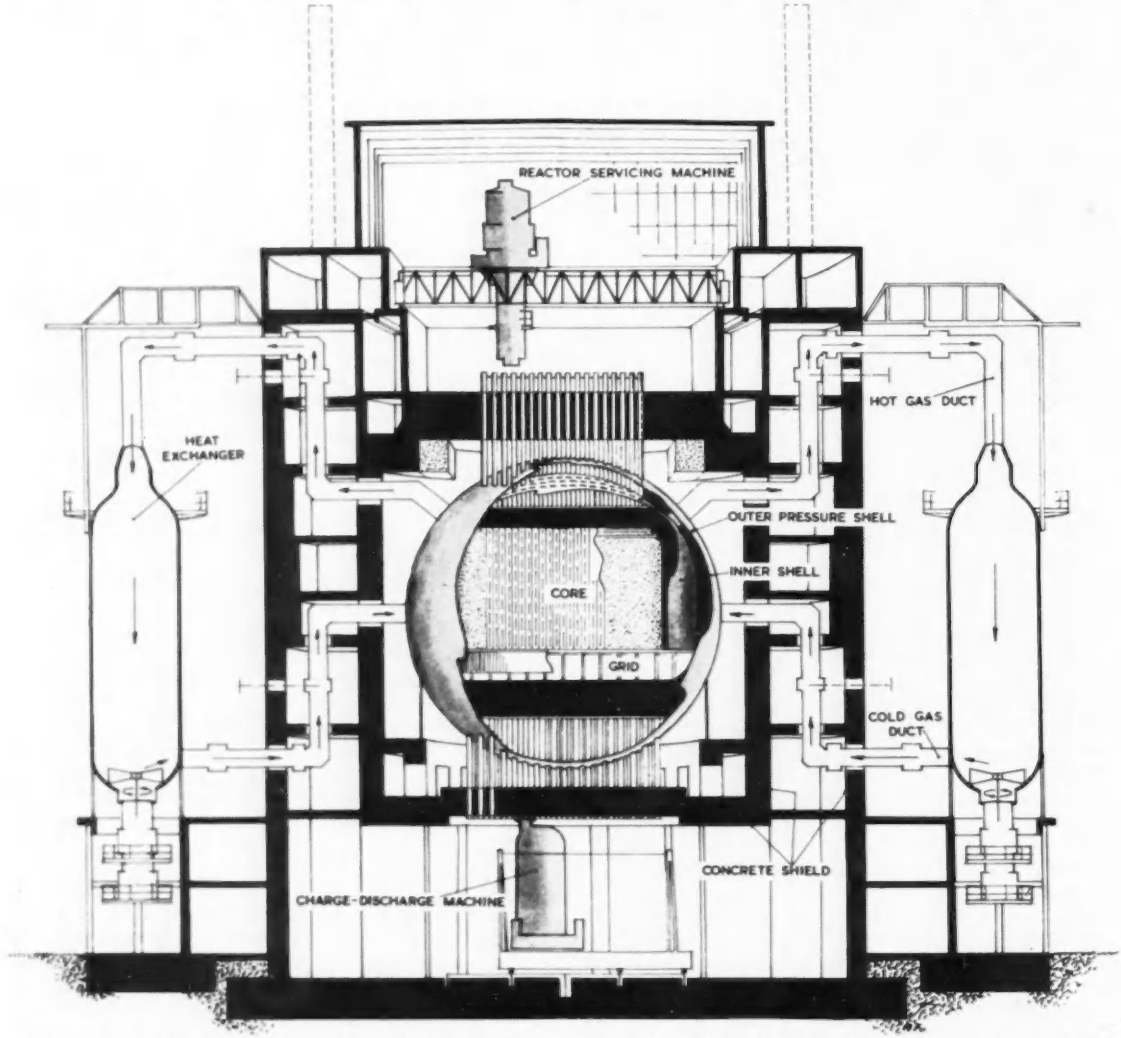


Fig. 2.—Diagram of the G.E.C.—Simon-Carves design of nuclear reactor, showing the direction of gas flow through the reactor core and heat exchanger.

The double-shell construction enables the best materials to be used for each purpose—a temperature resistant steel for the hotter, inner shell, and a tough, non-brittle steel for the spherical vessel which has to withstand the full working gas pressure.

Protection from nuclear radiation is provided by a 9 ft.-10 ft. thick concrete biological shield surrounding the core and forming one face of the 180 ft. high reactor building.

Charge and Discharge.

Charge and discharge of the fuel elements in a channel, ten at a time, is accomplished by a single remotely-controlled machine situated in a shielded chamber beneath the reactor.

For a base load power station it is obviously undesirable to have to shut down the reactor to change the fuel. The charge/discharge machine is, therefore, designed so that the removal of spent or damaged fuel elements and the charging of fresh fuel can be carried out while the reactor is on load and under pressure.

The charge/discharge machine is controlled from a room in the reactor building where the sequence of operations is viewed on closed-circuit television screens.

It has been mentioned before that the steel grid supporting the core divides the 3,288 fuel channels into " charge groups " of 36 channels each.

The channels are continued downwards through the grid by " fixed channel tubes ". In any one charge group, the fixed channel tubes are bent inwards into gentle curves so that their open lower ends can be fed from a point below the centre of the group.

Vertically below this centre line is a standpipe for each charge group—101 in all. Thus through each of these 101 standpipes any one of 36 fuel channels in a charge group can be reached by the charge machine.

The standpipes project upwards through the spherical shell and downwards to a point just below the biological shield forming the roof of the circular charging chamber. The lower ends of the standpipes are sealed with a steel door protected by a concrete shielding plug.

The charge machine vessel is approximately cylindrical, 30 ft. high, and capable of withstanding the full gas operating pressure. It is seated in a carriage mounted on four wheels. The carriage wheels run on tracks which are in turn mounted on a turntable spanning the diameter of the charging chamber. The turntable runs on two concentric sets of tracks and can rotate through 360°. Thus by rotation of the turntable and movement of the carriage along it, the nozzle in the top of the charge machine can be aligned directly beneath any chosen standpipe.

Control Rods.

There are altogether 208 channels in the reactor core structure which can be used for control rods, each control channel being associated with 16 fuel channels. In practice, not all these core channels will contain control rods. The control rod mechanism consists of a flexible stainless steel wire rope wound on a conically-shaped drum driven by a low-frequency permanent magnet motor. Each control rod is moved in or out of the core by applying a 3-phase supply to the motor stator ; the rods are held out of the core by reducing the frequency of the supply to zero, i.e. a d.c. condition.

The control rods themselves consist of a specially-developed lightweight boron-containing material canned in a stainless steel sheath. Short lengths assembled in this way are then placed within the main control rod tube. The complete control rod is 21 ft. long and 2 in. in diameter.

Steam Raising Units.

Heat is extracted from the nuclear reactor by a coolant gas, carbon dioxide, circulated throughout the system under a pressure of 150 lb. per sq. in. Gas passes upwards through the fuel channels in the reactor core, becomes heated, and is led away to the steam raising units where it gives up its heat to water with the formation of steam.

Eight units are radially disposed in pairs round each reactor. They contain banks of steel tubes through which the water and steam flow; as with the fuel cans, the steam raising unit tubes are finned to provide an extended surface and thus improve the efficiency of heat transfer.

The sixteen units for the complete station contain about 300 miles of tubing.

In the base of each 210 ton unit is an electrically driven 2,200 h.p. blower which recirculates the cool gas through the reactor.

Turbine Hall.

Steam from the steam raising units is piped over a bridge to the 700 ft. long turbine hall containing six 60,000 kilowatt dual pressure turbo-generator sets. Apart from all the ancillary feed heating and condensing plant, the turbine hall also houses the main control room in which the control of the reactors, heat exchangers and turbo-generators is centralised.

Cooling Pond.

Between the two reactor buildings is an 18 ft. deep cooling pond in which the irradiated or spent fuel elements are allowed to " cool-off " radioactively before being re-processed.

Heavy Engineering and Plant

STEAM TURBO-GENERATORS.

The total capacity of plant commissioned during 1956 has again exceeded that of any previous year. This total of just under 500 MW, as compared with last year's record of 410 MW, includes six 60 MW sets, five for the Central Electricity Authority and one for the Wilge Power Station of the Electricity Supply Commission of South Africa ; also three 30 MW sets.

At Ince all sets have now been commissioned, which completes this 240 MW power station. The first two 60 MW sets at the Hams Hall 'C' Power Station have been commissioned and the third and fourth sets are under construction on site. This 360 MW station, comprising six 60 MW sets, is scheduled for completion later this year. The latest extension to Bloemfontein, covering two 10 MW sets commissioned during the year, is shown in fig. 1.

Important among overseas orders received are the two 60 MW sets for the Electricity Commission of New South Wales—Wallerawang Power Station ; the 30 MW set at the Mount Isa Mines, Queensland ; and a large blower installation for India.

Of special interest also is the order for the Atomic Energy Authority's nuclear station project at Dounreay, for which Ewbank & Partners are consultants. The order covers one 15 MW set which utilises the heat from the fast breeder reactor, understood to be the first of this type in the world. The designed steam conditions are comparatively low, being 150 p.s.i.g., 518 deg. F., necessitating special attention to design for a set of this capacity. Reference has been made on page 3 to the contract for 360 MW of steam turbo-plant in the South of Scotland Electricity Board's nuclear power station.

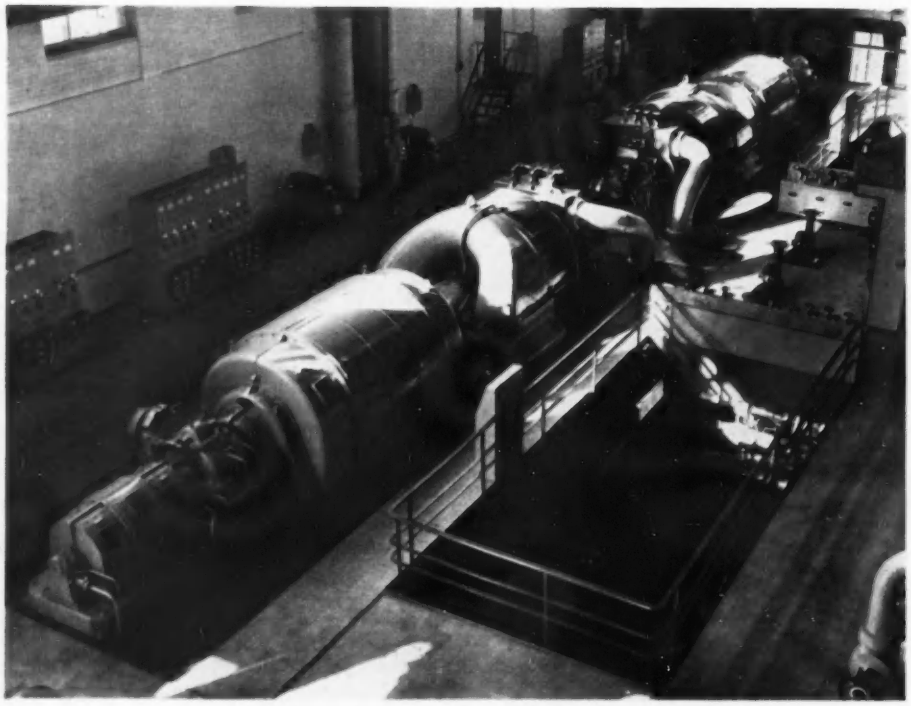


Fig. 1.—Turbo-alternators in the latest extension to Bloemfontein power station.

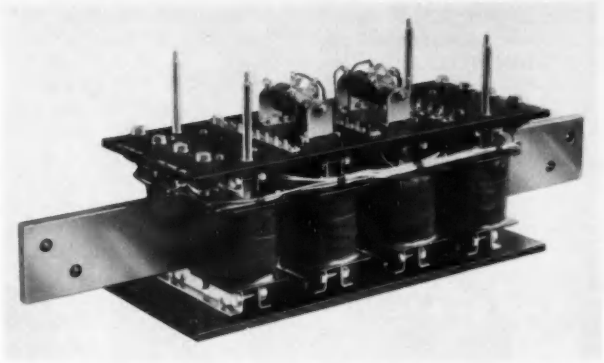


Fig. 2.—Magnetic amplifier assembly for the new design of rotor temperature indicator.

DEVELOPMENT.

The development of the 120 MW reheat turbine is illustrated by the sectional arrangement shown on page 8. Following this project, the consideration of larger reheat turbines has been advanced both in design detail and component testing, such as blade root fixing and the patented shrouding used on the long exhaust blades. Much progress has been made also in developing new techniques in the investigation of blade vibration. New designs resulting from this work cover reheat machines of 275 MW capacity in a single line at 3,000 r.p.m., also 200 MW in a single line at 3,000 r.p.m., as well as 200 MW in a single line at 3,600 r.p.m. for 60-cycle systems.

Still larger ratings in cross-compound arrangement follow naturally from these developments and a set of 550 MW rating arranged in two 3,000 r.p.m. lines of equal power is now under examination. This would have an H.P. cylinder on one line, a primary I.P. on the other and a multiple exhaust system, each flow being of the same physical dimensions as the large L.P. blading of earlier developments.

During the year special consideration had to be given to the requirements of atomic power plant, demanding the efficient use of steam at two different pressures and at temperatures that involve special considerations due to the wetness of exhaust steam. Although these developments were well within established design experience, many governing problems and design details received particular attention.

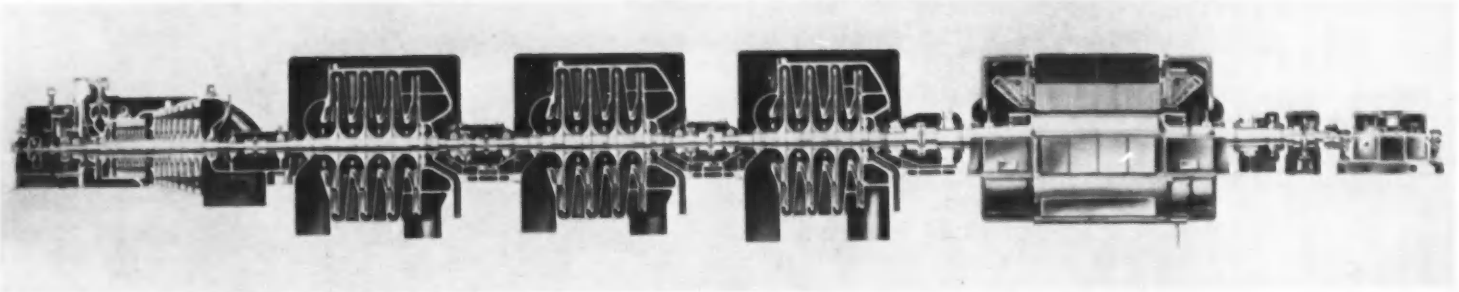
The atomic plants have also brought forward new problems in centrifugal impellers for gas, which have been the subject of both design and test investigation.

The development of direct cooling for the rotor windings of hydrogen-cooled alternators and the comprehensive tests which have been carried out on a prototype winding formed the subject of an article in a previous issue of this Journal.* The robust nature and neat appearance of an actual winding can be seen in fig. 3, which shows the rotor of a 60 MW unit in course of winding.

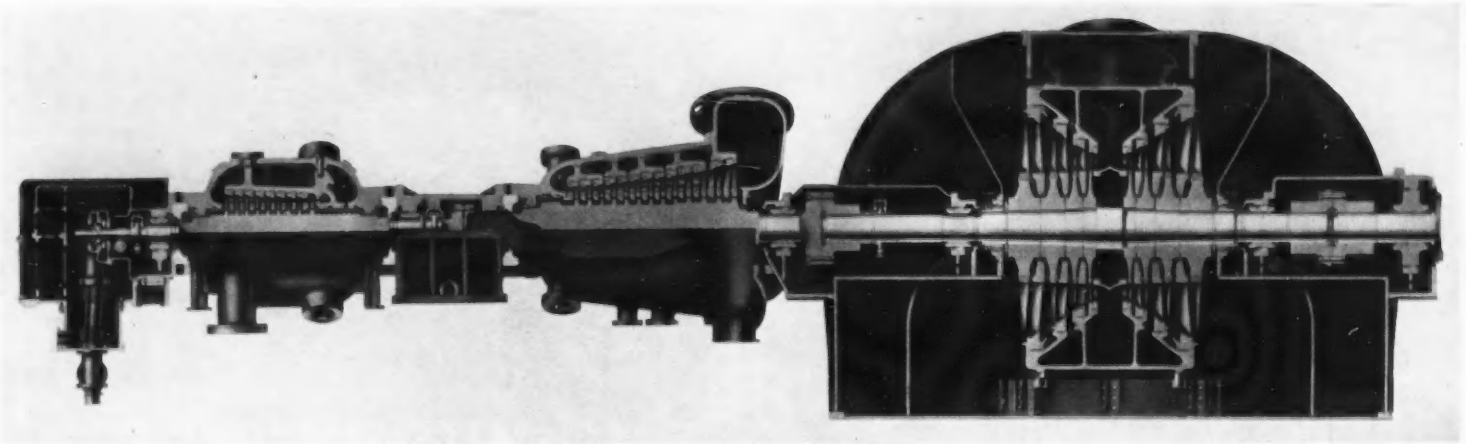
Concurrently with the development of direct cooling for rotors, a similar investigation was made on stator windings, but until transport weight becomes of overriding importance, it is not considered that the additional complication could be justified. For the larger units, however, say above 200/250 MW, direct cooling in some form will be essential if building on site is to be avoided. Alternative designs have been prepared and a research programme initiated using either hydrogen or a liquid as the cooling medium. As with the rotor, the main object has been to achieve an arrangement which is sound mechanically, as well as efficient thermodynamically, and at the same time to depart as little as possible from present practices in insulation and

* *G.E.C. Journal*, Vol. 22, pp. 155-160, July, 1955.

Fig. 3.—A direct-cooled rotor in course of winding, showing fitting of segmental intercoil packing.



Section of one of the eight 44,000 h.p. compressor-exhauster sets to the order of the Ministry of Works, each comprising one H.P. and two L.P. compressors driven by an 8,000 h.p. steam turbine and 36,000 h.p. synchronous motor. The compressors are arranged to run either in series when the two L.P. compressors discharge into the H.P. machine, or in parallel when the three machines discharge into a common main. Under the former condition each unit supplies 157,000 cu. ft. per min., at 140 p.s.i.g. and under the latter 212,000 cu. ft. per min. at 49 p.s.i.g. The machines will also operate in series or parallel on exhauster duty.



Section of 120 MW turbine operating on 1,500 p.s.i.g., 1,000 deg. F., reheat 1,000 deg. F. H.P., I.P. and L.P. casings have solidly coupled rotors and the machine has a single thrust bearing. The H.P. casing has four radial steam inlets with piston type joints into the inner casing, which contains the full pressure. Reheat steam enters the I.P. cylinder which also has radial pipes to ensure symmetrical heating. The machine is provided with six feed heating stages.

winding techniques. A scheme has now been developed and patented which reduces to a minimum the discontinuities in the stator winding insulation, and allows any metal-to-insulation joints that may be necessary in the cooling circuit to be located outside the stator enclosure.

In order to obtain experience of the mechanical details of the winding technique, direct cooling will be applied in the near future to the stator of one of the 60 MW or 120 MW machines at present on order.

The design of the temperature indicator for the supervision of the rotor temperature of large alternators has been simplified. This device ensures that the prescribed ceiling temperature of the rotor is not exceeded and enables the necessary corrective action to be taken immediately, should a fault develop. It measures the resistance of the rotor winding, and the reading is calibrated in units of temperature. No relays, contactors or electronic devices are used, resistance measurement being made by a continuously acting self-balancing resistance bridge, operated by a push-pull magnetic amplifier (fig. 2) which supplies a small reversible a.c. motor. A remote indicator and recorder can be provided if required.

Ranges of standard high-frequency alternators and associated control equipment have been developed to meet the very stringent requirements for waveform and close voltage regulation demanded by special types of radar and electronic loads.

TURBINE SUPERVISORY GEAR.

Many large power stations now being built are arranged to operate on the unit boiler/turbine system and the boiler, turbine and alternator are normally controlled from a common control station which may be situated some way from the turbine itself. The use of turbine supervisory gear is, therefore, being extended to give the operator full information about conditions in the turbine during starting up and running.

Previous installations have included equipment for measuring and recording the axial expansion of the H.P. rotor relative to its casing and also for detecting any eccentricity in the running of the H.P. shaft. On larger sets, the equipment is being extended to cover the I.P. turbine, and the total expansion of the H.P. casing will also be recorded. A further instrument will record the difference in temperature between the steam entering the turbine and the turbine casing, and detectors fitted to each bearing along the set will indicate any vibration occurring at these points.

The original circuits used for measuring these items have been modified to simplify the equipment, and to improve the accuracy of the readings.

Where the instruments are required for mounting on a remote combined boiler/turbine control panel, a small separate cubicle will be provided to house the special circuits, magnetic amplifiers, etc., associated with this gear. This cubicle will be placed adjacent to the turbine to give reasonably short leads to the various detectors. Local instruments for calibration purposes will be provided on this panel but the main instruments and recorders will be remotely connected on the main panel as required.

CENTRIFUGAL COMPRESSORS AND BLOWERS.

The Company has on hand a large number of centrifugal blowers and compressors, chief of which is the compressed air installation, believed to be the largest in the world, described in last year's Progress article. The first two of these eight sets, each comprising an 8,000 h.p. turbine, two L.P. centrifugal compressors, one H.P. centrifugal compressor and a 36,000 h.p. synchronous motor, are now being erected on the test pits at Erith.

The turbo-blower plant for the new Government of India Steel Plant at Durgapur covers four blast furnace turbo-blowers, each of a maximum capacity of 130,000 cu. ft. per min., under the high ambient temperatures prevailing. This complete steelworks project is being undertaken by the Indian Steel Works Construction Co. Ltd., a consortium of British firms.

Following on the very large compressor installation mentioned above, further instructions from the Ministry of Works cover a most interesting application of an air expansion turbine coupled to an alternator of 5,000 kW rating. From the exhaust of this turbine large quantities of sub-normal temperature air are obtained for purposes of research.

The comprehensive power plant contract carried out at Colvilles Ltd., Ravenscraig, Motherwell, is now being commissioned and it is expected to complete the station well in advance of requirements.

The motor-driven compressor, with a capacity of 25,000 cu. ft. per min. at 100 lb., installed at the Rustenburg Platinum Mines, South Africa, was also commissioned.

Orders covering blower and compressor plant also include a turbo-driven compressor for the Shell-B.P. refinery in Essex, having a capacity of 39,000 cu. m. per hour at 65½ lb. pressure, and a repeat order for Bairds & Scottish Steel Ltd. which covers a turbo-blower designed for 48,000 cu. ft. per min., 25 lb. pressure. The Scottish Nuclear Power Station contract increases the Company's programme by sixteen 2,200 b.h.p. motor-driven centrifugal CO_2 gas circulators.

MECHANICAL ENGINEERING.

Mining Plant.

A comprehensive project is in hand for the exploitation of a manganese ore deposit in South America. The planned output is 30,000 long tons of manganese concentrates per month. Three identical crushing and washing plants are to be installed during the period 1958 to 1960. Two plants will be sited back to back, and the third some two miles distant at the far end of the ore body.

Each plant will incorporate single roll and jaw crushers, combined blade mill trommels, and rake classifiers. Water will be supplied through a 20 in. main from a pumping station three miles distant,

the plants each requiring 600 tons of water per hour for a feed of 125 t.p.h. The manganese concentrates will be stored in 5,000-ton stockpiles fed by conveyors from the plants. Underground reclaiming conveyors will load the ore trains for transport to the port terminal.

Eventually, a central diesel power station is expected to house at least four 800 kW and one 375 kW diesel alternators. Part of the power requirements for the first phase of the plant has been ordered already. Distribution will be at 6,600 volts by a ring main some seven miles in length.

IRON ORE CONCENTRATION PLANT.

A new mill for a mining company in West Africa will treat 100 tons per hour of hematite ore, this being additional to the capacity of an existing mill, much of which was supplied by the G.E.C., where 200 tons per hour are treated. The new plant will be arranged so that a further section, also of 100 tons per hour capacity, can be conveniently added at a later date if required. The equipment is of particular interest in that Humphreys spirals will be used to carry out the concentration process. Opencast mining will be carried out by rooters and 25-28 ton scrapers. The ore will be brought by the scrapers to a heavy grizzly, 14 ft. 6 in. wide × 48 ft. long, set over a concrete bunker serviced by four 36 in. wide × 5 ft. long Sherwen heavy-duty feeders.

Electrical equipment of the plant will include a 1,000 kVA, 3-phase, 3,000/500 V transformer, control boards, cabling, wiring, lighting installation, switchgear and starters. There will be 29 motors of squirrel cage and slipring types, ranging from 100 h.p. to 3 h.p. and totalling 1,127 h.p.

HEAVY-DUTY PAN FEEDER.

A heavy-duty pan feeder has been completed recently for a large new cement works near Stoke-on-Trent. The machine is 6 ft. wide and 19 ft. long between shaft centres, 5 ft. 6 in. wide between skirt plates, and is required for feeding hard mountain limestone to a 42 in. gyratory crusher. Initial capacity will be variable between 300 t.p.h. maximum and 100 t.p.h. minimum ; this will later be increased to be variable between 600 t.p.h. maximum and 200 t.p.h. minimum.

Initial feeder speeds of $7\frac{1}{2}/2\frac{1}{2}$ ft. per min. will be used, which can later be doubled by changing the worm gear ratio.

WINDING ENGINES.

A 1,100 h.p. winder commissioned at Avon Colliery some two years ago was the first to use the Company's patented system of speed control for a.c. winders. Its satisfactory performance has led to orders being placed for a further thirteen equipments, of which ten are in service, including the fully automatic 3,000 h.p. skip winder at Cwm Colliery (p. 21). For this winder the control gear incorporated a creep speed regulator and brake impulse timer in order to provide the required degree of accuracy in decking.

The creep speed regulator automatically introduces a correction dependent upon the load and operates throughout the deceleration period. The brake impulse timer is a further refinement which takes account of the actual speed immediately before decking and slightly advances or retards the instant of braking as may be necessary. It is essentially a motor-operated rotary time switch set in motion by an impulse from a shaft switch and reversed by a second impulse from another switch located at a second check point

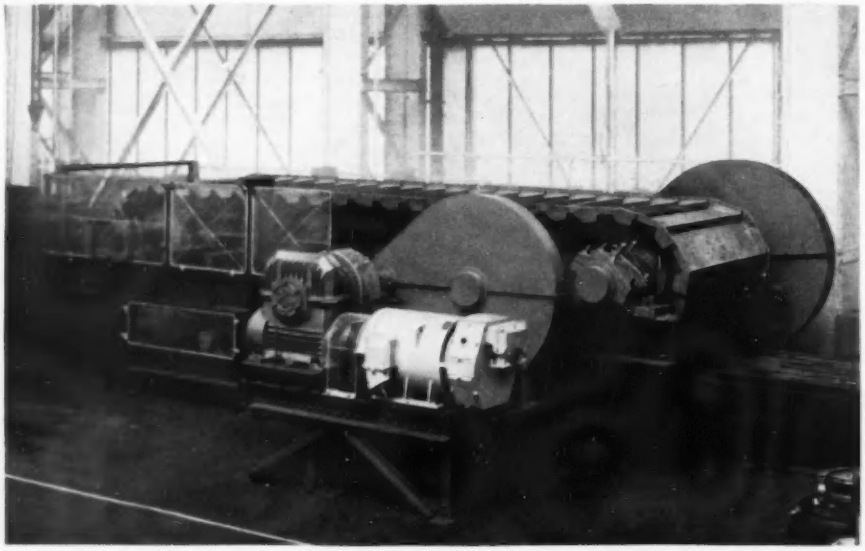
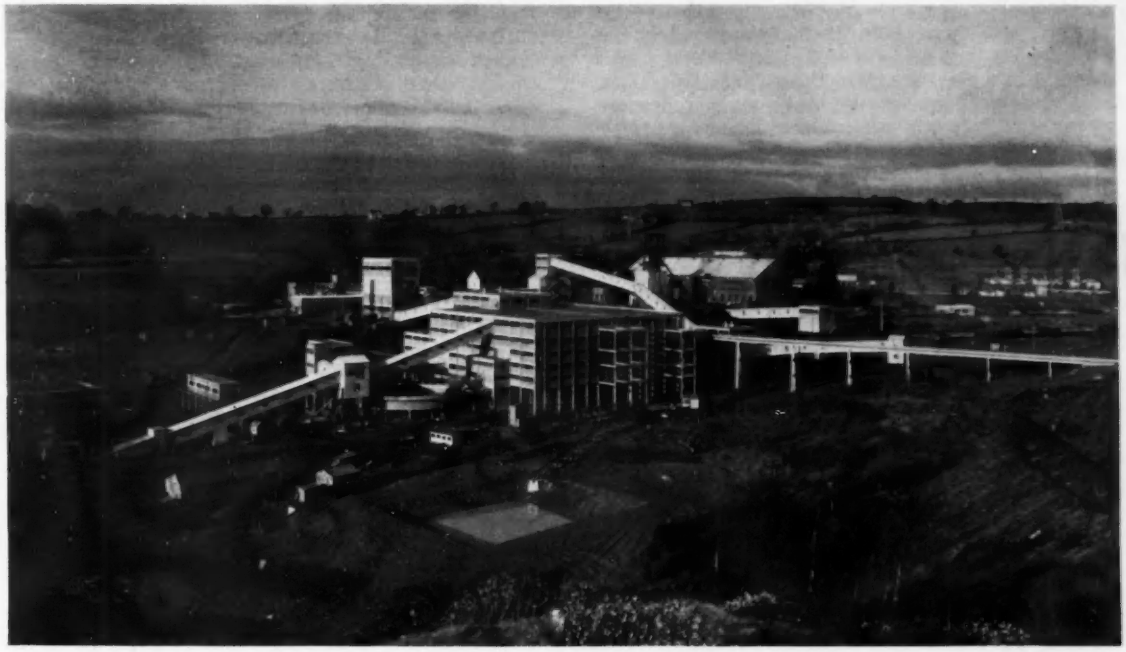


Fig. 4.—Heavy-duty pan feeder.



The two identical but separate washeries at the Cwm Colliery coal preparation plant, commissioned during the year, are each designed to treat 200 tons per hour of run-of-mine coal.

The 3,700 h.p. geared d.c. double-drum winder at Silverwood Colliery.

a few feet from the first. The angle traversed by the moving contact arm between the two impulses, i.e. between the instants when the cage passes check points, determines the time delay of the brake application, since the signal to the brake solenoid is given when the contact arm encounters an adjustable contact on its return travel. The adjustment of this contact allows for the inherent slight time-lag of the brakes.

A recent development is the automatic rope creep compensator for single-rope or multi-rope friction winders. In normal operation any tendency for the rope to creep over the driving wheel is to a large extent self-cancelling, but if circumstances call for a succession of heavy loads in one conveyance only, creeping becomes cumulative and would result in faulty operation of the depth indicator and other safety devices. The rigid coupling between the wheel and the depth indicator is therefore replaced by a differential gear, the cage of which may be rotated by a small motor to alter the angle between the wheel shaft and the depth indicator drive. This motor is energised to apply positive or negative correction by a fixed amount depending in direction upon the appropriate correction contactor. This keeps the error due to creep within prescribed limits.

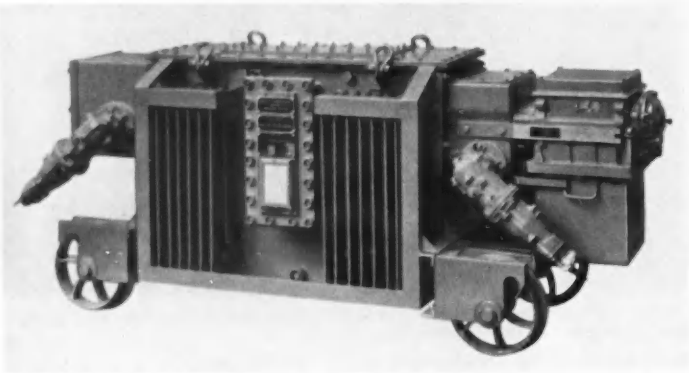


Fig. 5.—150 kVA transportable mining substation fitted with H.V. circuit breaker and L.V. cable coupler adaptor with instrument chamber.

In the past, automatic speed control, particularly during the deceleration period, has been effected by cam controllers driven from the winder shaft. Such controllers tend, however, to become increasingly complicated if the required precision near the decking level is to be achieved. A new system has been devised in which this control is effected by a geared potentiometer. By suitable grading of the potentiometer resistance, the deceleration curve may be predetermined to comply with any desirable form.

The practice of using a potentiometer regulator to provide the pattern speed signal in the Company's speed control systems has been dropped in favour of an induction regulator coupled to the driver's lever. A saturable reactor in the output circuit of the induction regulator ensures that a very fine control is obtainable at low speeds, i.e. it introduces the desirable non-linear relationship between lever movement and control output. Further advantages are the elimination of the moving contact system associated with a speed regulator, and reduced inertia so that less effort is required to operate the driver's lever.

Geared potentiometers and induction regulators are being incorporated in the control systems for the 4,500 h.p. d.c. winder for Mount Isa Mines, which will be arranged for push button operation, and for the 4,100 h.p. d.c. multi-rope friction winder for the Driefontein Gold Mining Co. Ltd.

During the year under review the two 3,700 h.p. geared d.c. double-drum winders at Silverwood (p. 11) and Cadeby Main Collieries have been put into commission, and have been found to fulfil all expectations, both on coal winding and on men and material duties. These winders are the first to use the Company's control exciter system, which has proved remarkably smooth in operation and responsive to small movements of the driver's control lever. Mechanically, these winders are duplicates and incorporate brakes operating on a variable pressure principle which has now been proved satisfactory over a number of years at various collieries. A further interesting feature of these equipments is the method of rope grooving by which the rope is led across the drum during coiling on the first layer. This is designed to eliminate the undesirable effect of "rope flap" experienced with the normal series of parallel grooves which hitherto have usually been employed for multi-layer coiling.

During the miners' holiday period at Cwm Colliery in the National Coal Board's South Western Division, an interesting conversion was successfully completed. The No. 1 shaft winder at this colliery had been originally installed in 1916 as a "diabolo" drum driven by two direct-coupled d.c. motors of 1,800 R.M.S. h.p. operating at a full-load speed of 27·7 r.p.m. This drum has now been replaced by two 18 ft. dia. by 4 ft. 6 in. wide parallel drums, the drums having been previously assembled on the new drumshaft to the rear of the old equipment while winding operations were in progress. During the changeover the old drum and shaft were removed complete and the new drums, complete with shaft, were rolled into position over the specially reinforced floor and lowered into the existing bearings. This operation, together with the erection of complete new pressure-operated brake gear, clutch and all control equipment, was satisfactorily completed and tested within the fortnight and the reconstructed winder was ready to lower the men at the end of the miners' holiday.

TRANSPORTABLE MINING SUBSTATIONS.

Since the introduction of the new design of transportable mining substation (fig. 5) to meet current Mining Regulations and the requirements of the National Coal Board Specification P109/1954, some 130 equipments, representing a total of over 24 MVA, have been supplied to British coal mines. The design is particularly flexible and permits a wide choice in the method adopted for controlling the incoming H.V. and outgoing L.V. supplies.

MATERIALS HANDLING EQUIPMENT.

A year ago reference was made to the wider appreciation of the advantages of iron ore blending plants. During the past twelve months there has been considerable evidence of this and export orders have been received for plants of this type for Belgium and India in addition to home orders for a new installation and extension to an existing one.

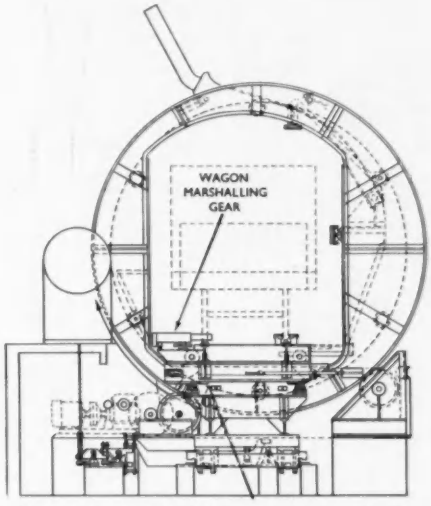


Fig. 6.—New design of 35-ton rotary wagon tippler.

A useful addition to the present range of wagon tipplers is a rotary tippler (fig. 6) embodying a very neat arrangement of weight-sustained top bolster.

A large proportion of the Department's work continues to be for the export market, an example being an ore stocking and reclaiming plant for East Africa comprising a stocking bridge and drag-scrapers for reclaiming. This plant is complete with all interconnecting conveyors ; its capacity will be 600 t.p.h. stocking and 2,300 t.p.h. reclaiming rate.

STEELWORKS.

The use of magnetic amplifiers in the control of steelworks and industrial drives is becoming increasingly popular. Drives for three continuous electrolytic tinning lines at present being supplied to the Steel Company of Wales make extensive use of this type of equipment for the co-ordination of a large number of helper roll drives and also for build-up and tension control of the reel drives. Because of the large number of amplifiers involved in this instance, a high-frequency supply is being provided to improve the performance and reduce the size of components.

In many cases magnetic amplifiers are replacing control exciters, so that static apparatus is used in place of rotating machines. However, where a fairly large control power of reversible polarity is required, the magnetic amplifier tends to become rather bulky and inefficient, and control exciters may still be the best solution. Thus for the auxiliary drives being supplied for the blooming, roughing and beam mills at the Lackenby works of Dorman Long & Co. Ltd., over fifty Ward Leonard generators are being controlled by a new design of control exciter particularly suited to this type of drive. In this design a quick-response speed control is achieved, while current-limiting is effected by saturation of the exciter field system, instead of by the metal rectifiers used in the normal current-limiting circuit.

It will be recalled that the excellent performance of the temper mills at the Trostre Works of the Steel Company of Wales resulted in contracts being placed for two further mills for the Velindre Works. These are now in commission (p. 19) and are generally similar to those at Trostre which were described fully in the July, 1953, issue of this Journal.

The new mills embody certain refinements resulting from the experience gained with the Trostre installation. Twin motor drives are used in order to reduce inertia, and the motor ratings have been increased from 1,000 to 1,250 h.p. Inching and threading of the strip through the mills has been made easier by adopting for the reel drive a combined speed tie with overriding current control. Improved accuracy in the hand control of the inter-stand tension, which was formerly effected by an adjustment of the speed tie, has been obtained by using a current-difference form of control. The changeover from hand to automatic control is made shockless by a " shadowing " system in which the automatic electronic gear closely follows the hand setting. The retardation rate of the whole mill is automatically determined by the uncoiler current, so that there is no risk of overloading this section of the plant. This is achieved by a magnetic amplifier which summates the tension and retardation components and reduces the retardation rate as necessary.

The two hot-strip coilers at the Abbey Works of the Steel Company of Wales have been supplemented by a third set. The three coilers are operated from a single control desk which incorporates a console type control switch. The development of this switch was an important contributory factor in the achievement of such a compact arrangement.

Overseas, the 4-high non-reversing cold-strip mill for Austral Bronze has been commissioned. The main driving motor is rated at 850 h.p. and is supplied from a Ward Leonard set with a separate generator for feeding either the 50 h.p. up-coiler or the 150 h.p. mandrel coiler. Tension control is effected by the G.E.C. control exciter system.

AIRCRAFT TESTING STRUCTURE.

For structure testing of Hawker aircraft, equipment has been supplied for submitting the aircraft wing assemblies to flight stresses and strains. It is generally similar to the installations known as "Cathedral" and "Abbey" at the Royal Aircraft Establishment, Farnborough.*

Eight loading units are provided, each mounted on a separate loading bridge and controlled by a 5 h.p. variable speed d.c. motor, which is complete with its own cooling fan driven by a constant-speed motor. Arrangements are made for hand-operation of each motor separately or for any number of machines to be operated collectively by an automatic hydraulic-electric system. Automatic operation provides for a steadily-increasing load up to a pre-set value or a repetitive load-unload cycle.

The armature voltage, which can be continuously varied, is derived from three grid-controlled thyratrons fed from the 3-phase a.c. mains. This voltage and consequently the motor speed are maintained at any set value by automatic adjustment of the grid bias. An electronic amplifier compares the output voltage of the thyratron with a stabilised reference voltage, any variation resulting in an immediate change in the thyratron voltage and so governing the motor speed. An overriding current limit control safeguards the motor from excessive currents during acceleration, while dynamic braking is included for quick stopping.

The oil volume in the hydraulic stressing system must be kept constant in order to ensure accuracy during a testing cycle. This is effected by summating the various ram positions. Each ram is coupled to extremely accurately graded variable resistors so that any deviation of a ram from its mean position produces an out-of-balance in a bridge circuit of which the variable resistors are a part. This operates the oil boost or leak valves through a sensitive relay and thus restores the oil volume.

RECTIFIERS.

The market for grid-controlled mercury arc rectifiers continues to increase as users recognise the advantages of this form of d.c. power unit both in reliability and ease of operation, particularly when used in conjunction with electronic and magnetic systems of control. The ability of this form of rectifier to provide power at a continuously variable voltage is sufficient in itself to ensure a steady demand for some years to come.

The grid-controlled rectifier is particularly suitable for supplying power to large variable-speed d.c. motors such as are used for rolling mills, a typical example being the drives for the 3-stand medium section mill at the Cleveland Works of Dorman Long (Steel) Ltd. Each of the 1,500 h.p. main stand motors is fed independently from a 12-phase, 2,150 kW, 850 volt rectifier equipment, using a closed-loop system of voltage control. Provision is also made for running all three motors from two rectifier equipments working in parallel. The method of grid control is similar to that used with considerable success on printing press drives, where a high degree of accuracy in the speed control of the motors is essential. The servo-amplifier is partly magnetic and partly electronic and includes current-limit features. With this form of control precise inching and crawling speeds are obtained.

Last year reference was made to the load tests which were carried out at the works on one of the 2,200/2,500 kW, 660/750 volt rectifier equipments for the Southern Region of British Railways. The satisfactory performance of the equipment at that time has been fully substantiated by on-site tests which have been undertaken in conjunction with the customer on the equipment at Brockley substation (fig. 7). The test lasted 12¼ hours, during which the average load was 115·5 per cent. of full load, the maximum load being 197 per cent. full load for a period of 5 minutes, while 150 per cent. full load was maintained for 3 hours 10 minutes.

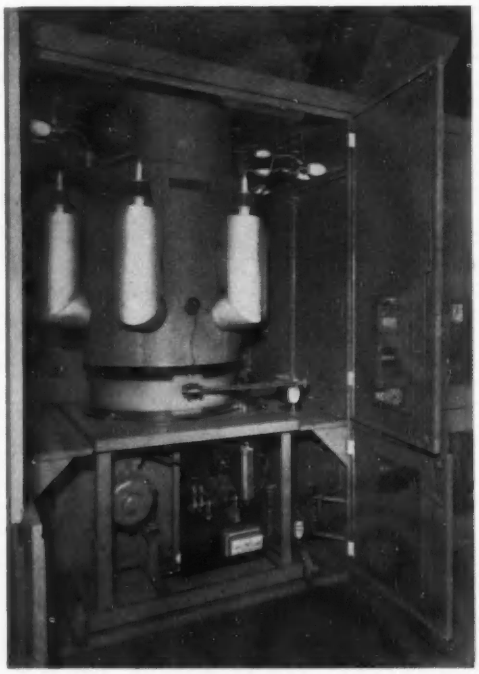


Fig. 7.—Rectifier cubicle at Brockley substation, Southern Region, British Railways.

In connection with the a.c. traction system now being adopted by British Railways, new types of single-anode mercury arc rectifier have been developed. They are small rectifiers specially designed to operate satisfactorily on rolling-stock, where the operating conditions present difficulties which are not encountered in substation plant.

* *G.E.C. Journal*, Vol. 17, pp. 96-103, April, 1950.

WELDING EQUIPMENT.

The portable single-operator a.c. welding set has been completely redesigned to comply with British Standard 638, group X, and the opportunity has been taken to incorporate improvements in the construction and appearance of the equipment.

Two models are available, one with three tappings for voltages of 380, 410, and 440, and the other with twelve tappings for voltages from 190 to 550, the tappings being covered by a domed false lid. Each is rated at 25·6 kVA and provides a current range from 21 to 425A in 49 steps, with a maximum continuous welding current of 320A. The degree of arc stability achieved is such that the plant will operate efficiently in conjunction with a very wide range of electrodes.

The range of welding chokes for use with multi-operator equipment has been extended to include a 450A unit, designed to provide welding currents from 48 to 450A in 36 steps. It is mounted in a circular steel tank and is similar in appearance to the present 300A choke.

Fig. 8.—65 in. 8-section coil lifting magnet.

LIFTING MAGNETS.

The range of circular lifting magnets has been extended and those of 56 in. and 65 in. dia. which were formerly built with 4-section coils as standard, can now also be supplied with coils of 6 and 8 sections. The 65 in. magnet fitted with an 8-section coil (fig. 8) is the largest in the range and weighs 14,480 lb. Its consumption when cold is 30 kW.

By increasing the height of the magnet to accommodate more coil sections greater lifts are obtained for a given magnet diameter. For example, an 8-section coil magnet of 56 in. dia. will handle approximately the same weight of material as a 65 in. magnet using a 4-section coil; while the lifting capacity of an 8-section coil 65 in. magnet when handling pig iron exceeds that of its 4-section coil counterpart by nearly 50 per cent.

For handling steel plates, bars, sections and tubes, a range of rectangular lifting magnets from 30 in. × 20 in. to 72 in. × 24 in. is now in production. Magnets of this design are particularly suitable for long loads as two or more can be spaced on a spreader beam to maintain equilibrium and ensure an adequate factor of safety.

Considerable attention has been given to details of design of both circular and rectangular magnets and many improvements have resulted in better performance and prolonged life.

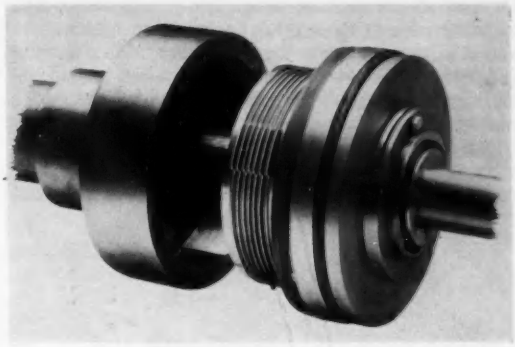


Fig. 9.—Multi-plate clutch.

CLUTCHES.

The range of magnetic clutches has been extended by the introduction of a multi-plate clutch (fig. 9) which has been designed to meet the need for a small unit capable of transmitting a high torque. Although at present this equipment is being produced only for Redler conveyor power shovels, it is expected that a wide market will develop.

FRACTIONAL HORSEPOWER MOTORS.

As there is a growing tendency in the Services to use power supplies at a frequency of 400 cycles, a range of small high-speed induction motors has been developed. These machines are designed to operate on 3-phase systems and have outputs up to ¼ h.p. at 10,000 r.p.m. By using class E insulation, with its high permissible temperature rise, the size of the motors has been further reduced, the overall dimensions of a typical ¼ h.p. machine being 2¼ in. square × 5¼ in. long, inclusive of the shaft (fig. 10).

In order to meet the demand for small 50-cycle, single-phase motors from 1/50 h.p. to 1/20 h.p. a new standard range of machines (frame size NEMA 36) is being developed. The stator stampings are secured

in a steel shell and the end brackets are almost flat so that it becomes economically possible to make these motors in many different core lengths. The starting winding is cut out by an external relay, but consideration is being given to fitting this relay within the motor frame.

Even smaller motors than the foregoing are required for certain applications, for which machines using two deep sheet metal pressings to form both the shell

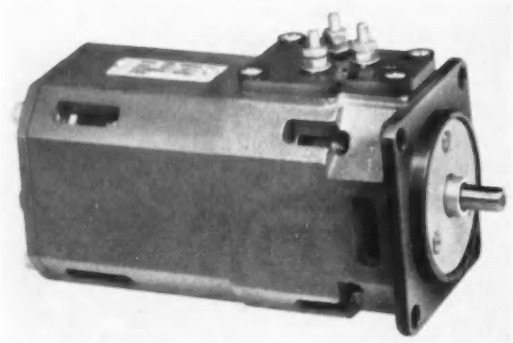


Fig. 10.—¼ h.p. high-speed induction motor for 400 c/s supply.

and end brackets have been designed. This construction has proved very satisfactory where the service conditions are not too arduous.

To supply the power required to operate equipment on railway rolling stock for automatic train control, a motor-alternator set with a rectified output of 12 watts at 12 volts has been designed. An interesting feature of the unit is the means adopted to ensure a sensibly constant output from the alternator. The excitation is compounded, using the armature current of the d.c. driving motor. Input to the set is 70 volts d.c., and the alternator has an output before rectification of 40 watts, 23 volts, 600 cycles.

Also of interest is the development of a motor-alternator giving a single-phase output of 700 watts at 400 cycles when running at 8,000 r.p.m. A supplementary 40 watt output is also available. This machine has been produced for the Services and may find ultimate use on fighting vehicles. The alternator, with all its ancillary apparatus, including the main contactor, voltage regulator and operating equipment, is enclosed in a compact cabinet, the general arrangement being shown in fig. 11.

WITTON LABORATORIES.

In addition to the more fundamental research carried out in the Research Laboratories at Wembley, a considerable amount of research and development work is taking place in the heavy electrical engineering group of factories at Witton.

Because of the nature of such products as alternators, transformers, switchgear, motors, rectifiers, etc., much of this work is carried on in the works themselves as well as in the Witton Laboratories. The laboratories have, however, been extended recently by the addition of a new block with a total area of 11,220 sq. ft. This new block incorporates an enlarged chemical laboratory, with all facilities for routine testing and special work; a mechanical test completely equipped to carry out tests on routine and new materials used in the Company's heavy engineering products; and comprehensive testing facilities in a new wing for fractional horsepower motors and fans including tropical testing, a British Standards fan test, anti-radio interference testing and life testing.

To cater for the continued application of light-current techniques to the control of engineering products, an industrial electronics laboratory has also been established for research and development concerned with electronic and magnetic amplifiers and servo-mechanisms; while in recognition of the importance of the finished appearance of the Company's products, special facilities have been provided in another part of the laboratories for the development and application of paints, varnishes and other surface finishes.

In keeping with the steady increase in the size of power transformers, the capacity of the 2½ million volt impulse generator in the High Voltage Laboratory has been increased to 80 kW seconds, which enables British Standard waveshapes to be maintained during tests on the larger transformer units.

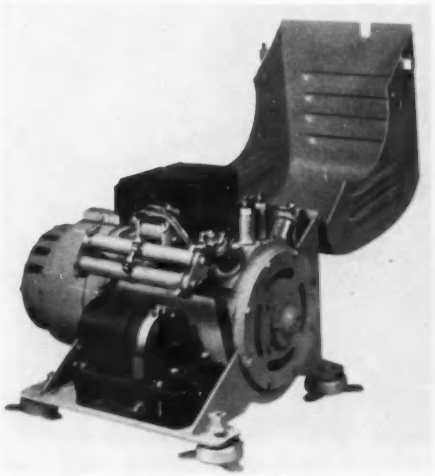


Fig. 11.—A 700 W, 400 c/s motor-alternator developed for Service use.

In connection with chopped-wave impulse tests on transformers—a subject of considerable interest in all the leading manufacturing countries of the world—successful use has been made in the High Voltage Laboratory of controlled chopping gaps to supplement the use of rod gaps.

The introduction of new kinds of insulating materials and their adaptation to various uses already established, has led to the application of new and more scientific methods of assessing the physical properties and behaviour of such materials under working conditions, particularly with regard to climatic testing.

To this end special temperature, humidity and pressure cabinets have been installed which enable the materials to be investigated over temperatures and humidities ranging from arctic to tropical conditions and pressures corresponding to those experienced at the extremely high altitudes reached by modern aircraft.

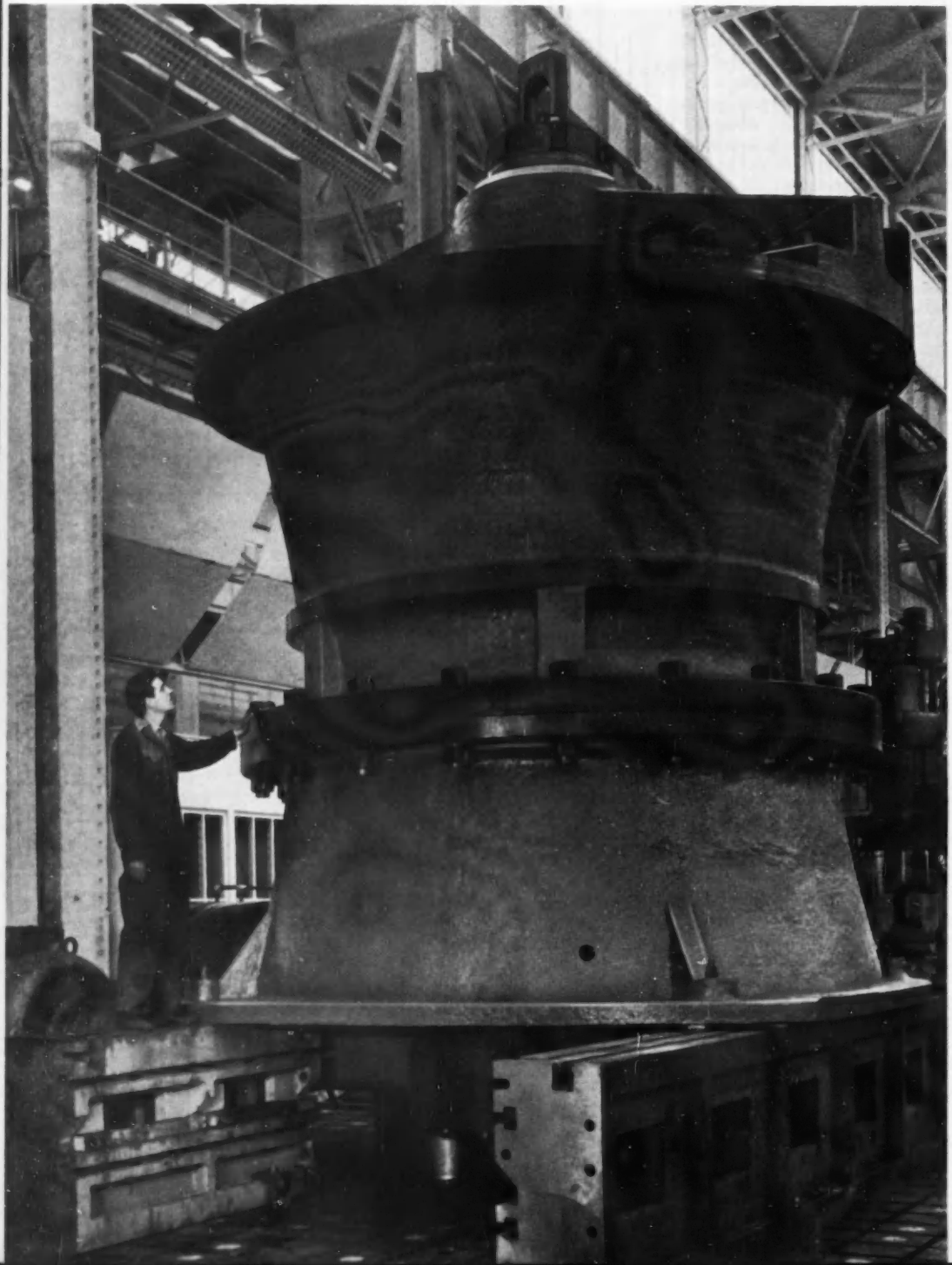
Electronic methods of measurement are playing an increasing part in the investigation of insulating materials and a large number of researches have been undertaken using the latest methods of ionisation detection to determine the corona inception and corona extinction voltages in insulation systems, one of the objects being to correlate this information with that derived from the more conventional power-factor/voltage measurements. In parallel with this work electronic dispersion measurement techniques have been used in connection with the study of the moisture content of insulating materials.

Further work on insulation has included the assessing of the ability of selected materials to withstand the presence of high-power arcs on their surfaces. Automatic apparatus has been used to carry out special repetitive tests.

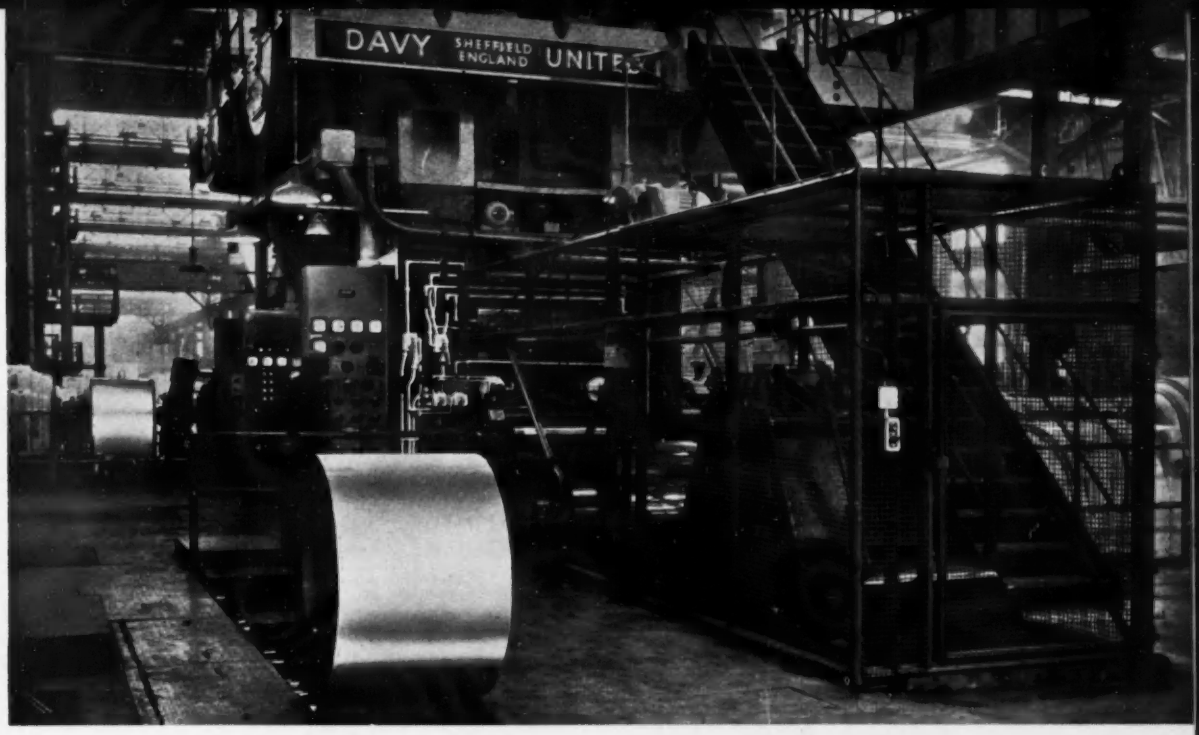
In addition to its direct service to the Works, the Fractional Horsepower Section of the Laboratories is concerned with the development of electronically-actuated balancing machines for use in connection with the different kinds of rotating electric machinery manufactured by the Company, ranging from large turbo-alternator rotors down to very small fractional horsepower machines. In the large number of these balancing machines produced to date, special attention has been paid to automatic operation, and to location of the amount and position of out-of-balance. The precision and accuracy attained far exceed anything thought possible a few years ago.

Fig. 12.—Electronic balancing machine for fractional horsepower motors, with the pre-set controls exposed.

Engineering Plant and Installations

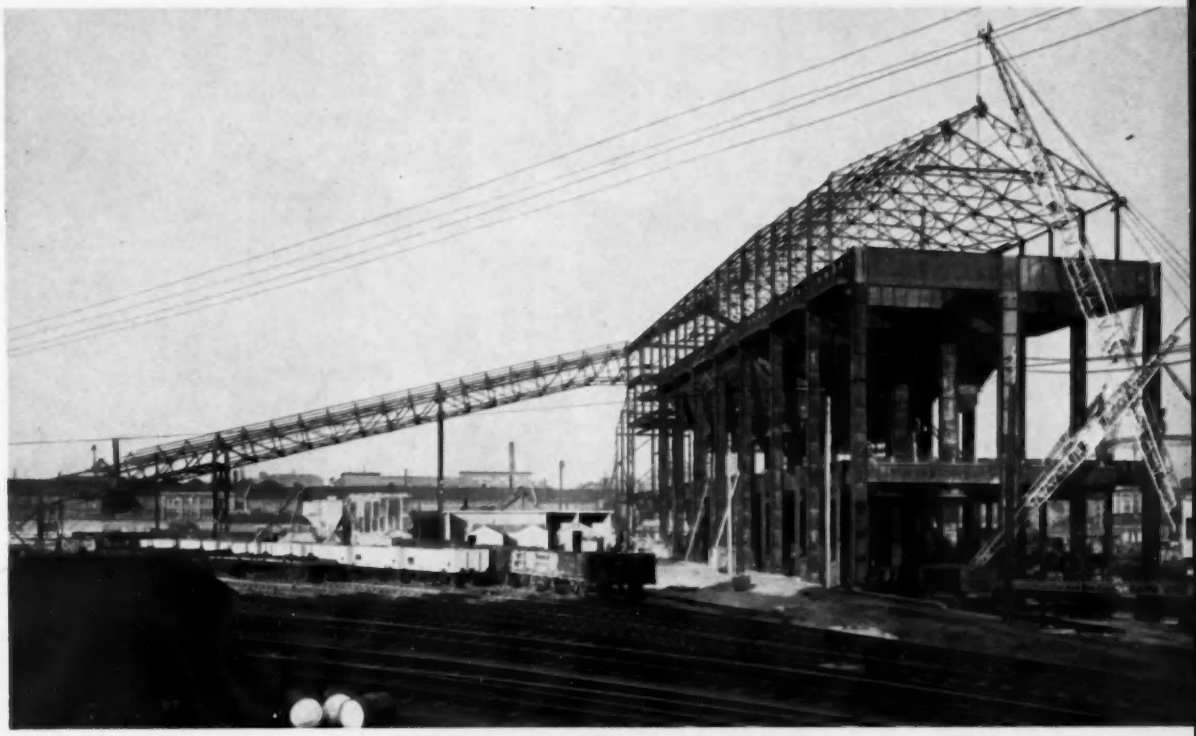


A 42 in. Symons primary gyratory crusher in the New Turbine Shop at Erith. The crusher is driven by a 300 h.p. motor and can achieve capacities of 1,000 t.p.h. Two of these machines are in course of manufacture for the Nordberg Manufacturing Company.



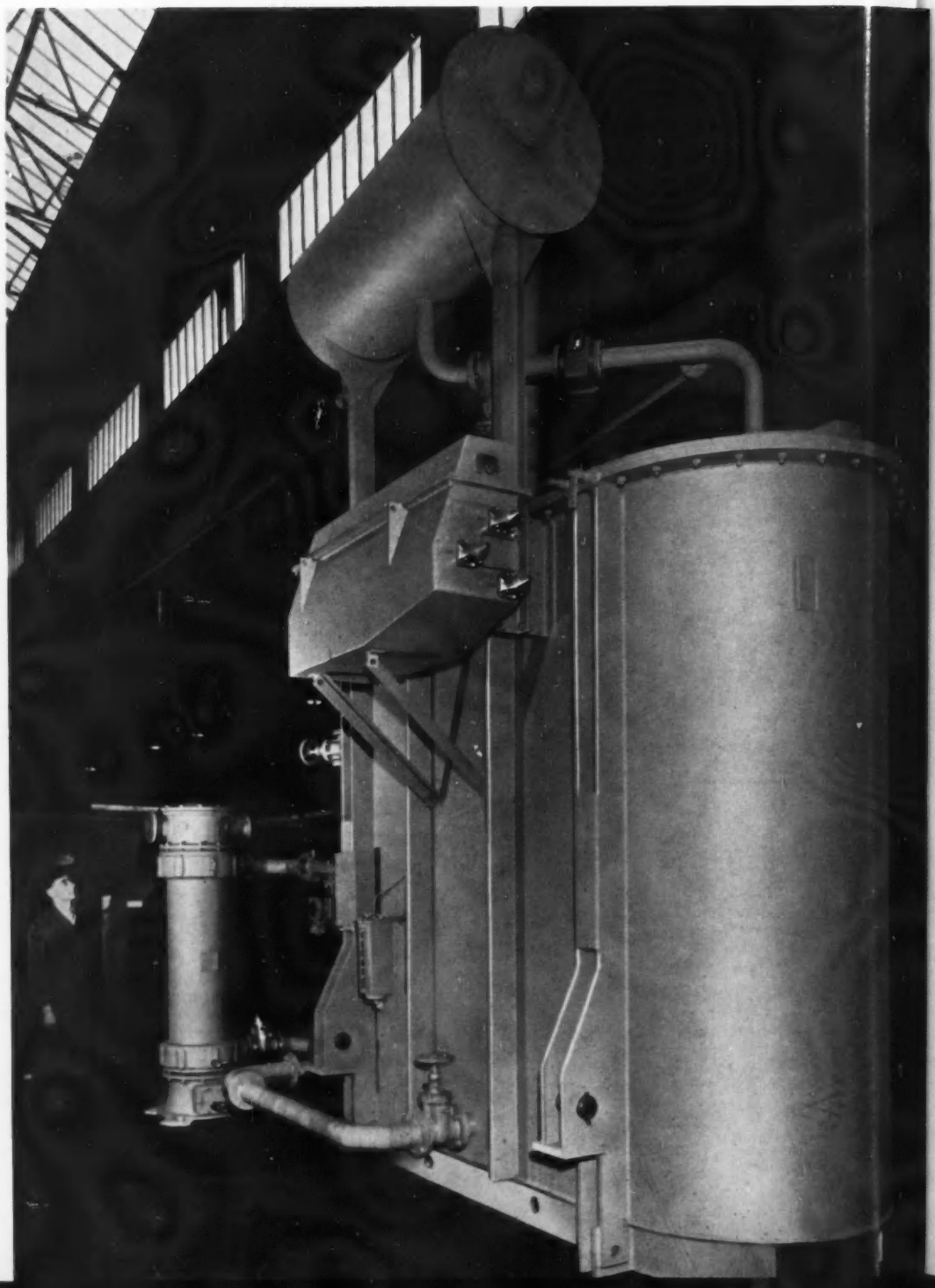
Two new 2-stand temper mills at the Velindre Works of the Steel Company of Wales have been equipped with electric drives incorporating the latest refinements in hand and automatic control.

[Courtesy Davy & United Engineering Co. Ltd.

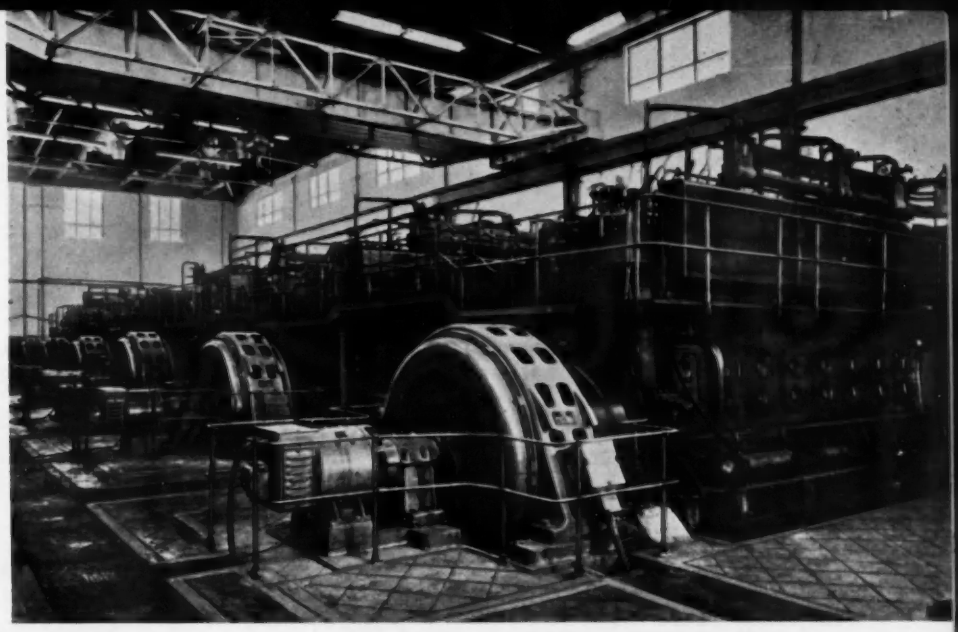


Ore handling and unloading equipment under construction at General Terminus Quay on the River Clyde at Glasgow. The installation is an essential link in the supply of iron ore to the Ravenscraig and Clyde Iron Works of Colvilles Ltd.

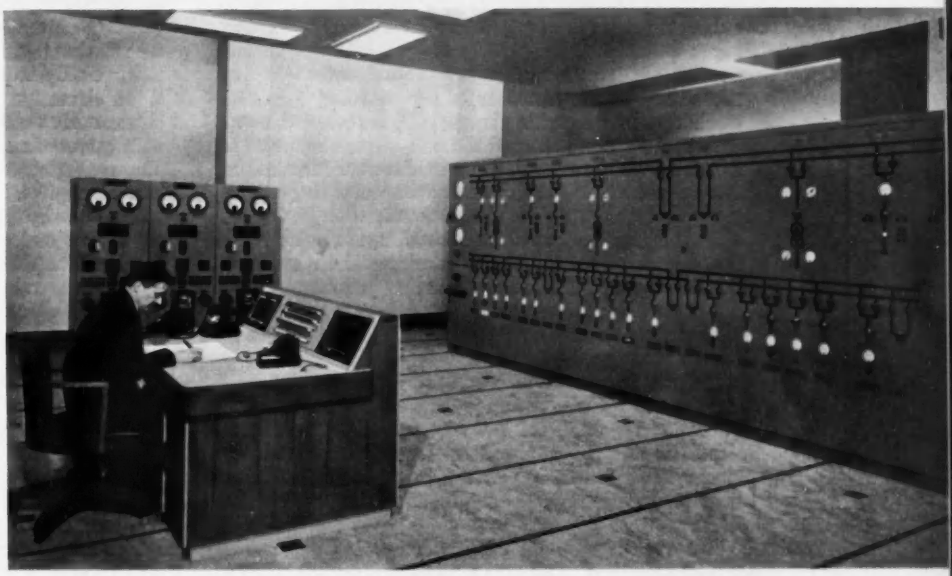
Engineering Plant and Installations



One of eight 27·5 MVA transformers for supplying 36,000 h.p. synchronous motors in a Ministry of Works air compressor plant for aeronautical research.



The main power installation of the Williamson Diamond Mines, Mwadui, Tanganyika, showing six of the nine 900 kW alternators driven by Ruston diesel engines.



Control board for the 22 kV and 11 kV switchgear at Newington House substation of the London Electricity Board, which will have an ultimate capacity of 60 MVA.

The fully-automatic 3,000 h.p. skip winder installation at Cwm Colliery incorporates a creep speed regulator and brake impulse timer for accuracy in decking.

Power Distribution and Control

TRANSFORMERS.

In designing power transformers of the high ratings demanded to-day, a far more detailed knowledge of the leakage flux field and impulse voltage distribution is required than was necessary or even feasible a few years ago. On a knowledge of the leakage flux field depends the calculation of the mechanical stresses arising from over-currents and of the eddy current losses which produce heating of the windings, shields and tank. On the impulse voltage distribution depends the ability of the transformer to withstand lightning discharges and switching surges. Both these problems defy an exact mathematical solution, but can be solved to a high degree of accuracy by methods of approximation.

The radial flux density at a given point due to any section of the winding in which the distribution of current is uniform can be calculated, but the mathematical formula involves four transcendental terms. Any winding can be divided into a number of such sections, but when it is realised that the flux density at scores of different points may have to be determined in order to arrive at the degree of accuracy required, the magnitude of the task becomes apparent. Similar calculations are also necessary to determine the axial flux density. Therefore for this work full advantage is taken of the electronic digital computer, which enables the designer to arrive at a solution so readily that these calculations are now undertaken as routine for all large transformers.

In order to ascertain the impulse voltage distribution, it is necessary to derive the capacitance network associated with the winding, taking into account fringing as well as interconnections. Digital computer programmes have been constructed to calculate this network and the initial voltage distribution direct from the design parameters. From this information the subsequent behaviour of a surge can be calculated, using various well-proven methods.

The foregoing methods may be adopted with confidence for designs of a form for which the accuracy of existing methods of calculation has been proved in practice. However, if a design involves completely new forms of winding, a model is first built, particular care being taken to keep the distribution of turns precisely similar to that in the full-sized transformer. It is then possible to derive relationships between the model and the transformer so long as capacitance has no effect on the particular characteristic under consideration.

When considering impulse phenomena, the capacitance network of the winding assumes major importance and a lumped capacitance network is connected at suitable points across the winding as suggested by Abetti.* The capacitances are chosen to maintain a unity time scale and excellent agreement has been found with the full-sized transformers subsequently built. This technique has provided valuable data for the development of methods of calculating electromagnetically-induced impulse voltages.

An electrolytic tank is in constant use for solving electrostatic problems. These include certain capacitance calculations and the determination of stresses by plotting the electrostatic fields. Considerable attention has been given to model-making techniques so that models can be made in the shortest possible time. In principle the electrolytic tank can also be used for heat flow problems, but it has been found more convenient to solve the relevant partial differential equations by the digital computor.

During the year under review large transformers with ratings of 36, 45 and 72 MVA and totalling over 650 MVA have been supplied to the Central Electricity Authority for outdoor substations at Crumlin, Coalville, Radstock and Rame and for power stations at Ince, Hams Hall and Barony. The 36 MVA units for the Barony Power Station are designed for forced-oil circulation with air-blast cooling and embody a system of directed oil flow within the windings whereby the temperature gradients are reduced and the efficiency of cooling improved.

Notable among the orders now in hand for the Central Electricity Authority is that for a 144 MVA generator-transformer with a voltage ratio of 145·3 kV/13·8 kV for Northfleet Power Station. This transformer, which will be the largest so far built by the Company, will embody forced oil circulation with water cooling.

The first of the eight 27·5 MVA transformers which are being supplied to the Ministry of Works in connection with their 352,000 h.p. air compressor plant for aeronautical research† is now completed. It will be noted from the illustration on p. 20 that a round-ended tank has been adopted. This form of construction provides ample strength with simplified bracing, resulting in a more pleasing appearance, and also reduces the oil content.

* *Trans. A.I.E.E.*, Vol. 72, Part 3, 1953.

G.E.C. Journal, Vol. 23, No. 1, pp. 7 and 12, January, 1956.

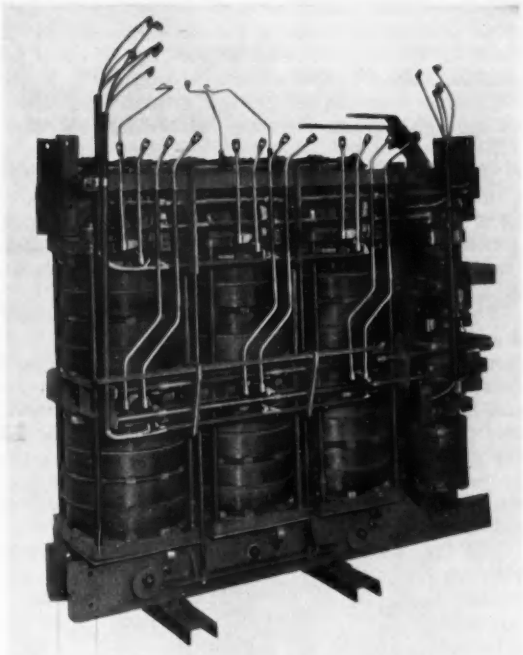


Fig. 1.—A 600 kW, 11,000/230 V rectifier transformer with composite core for 12-phase service.

Investigations continue into the use of cold-rolled, grain-orientated steel for transformer cores with a view to exploiting still further its special characteristics. Since its introduction, nearly a thousand transformers have been built using cores of this material. These include 7·5 MVA units for Hong Kong and 30 and 40 kVA double wound transformers for the Admiralty, the latter being designed to withstand the specified shock tests. Three 10 MVA transformers for Hong Kong and a 5/6·25 MVA unit for Chile, which will also use this type of core, are now in course of manufacture.

Three 2·5 MVA, 60-cycle units have been despatched to Canada for service in a pumping and generating station at Niagara and distribution transformers of a total capacity of 11 MVA have been completed for Nigeria.

When rectifier transformers are required to operate as 12-phase equipments, two 6-phase units having respectively delta and star-connected primaries may be considered preferable to the more usual quadruple zig-zag connection. Formerly the transformers were built as two separate units, but in the latest version of this system the two transformers are wound on a single core, thereby providing a single unit of very compact and robust construction (fig. 1).

For use in automatic voltage regulators for the Admiralty, hermetically sealed, oil-filled, C-core and laminated transformers, chokes and magnetic amplifiers have been built to withstand mechanical vibration and shock tests. They are designed for frequencies of 400, 1,600 and 2,400 cycles per second.

A new design of airfield boundary lighting transformer has been developed for supplying 35/40 watt and 200 watt lamps. The transformer is built in a sturdy cast-iron case which is filled with bitumen so that the complete unit is suitable for burying in the ground and no separate container is necessary. The service requirements for this class of equipment are recognised as being severe and exacting and are fully met by this design.

OUTDOOR SWITCHGEAR.

The existing range of 132 kV oil circuit breakers has been extended to include units capable of interrupting 5,000 MVA. The tank, bushings and mechanism are identical with those of the 3,500 MVA type, the increased breaking capacity having been achieved by designing new contacts and arc control pots. The fact that the main components are common to both the 3,500 and 5,000 MVA breakers is of distinct advantage to users, in that units of lower breaking capacity already in service can very easily be up-rated to 5,000 MVA on site when increased severity of system conditions makes this desirable.

The 5,000 MVA breaker has successfully undergone A.S.T.A. certification tests in accordance with B.S. 116/1952 and has also been tested under A.S.T.A.

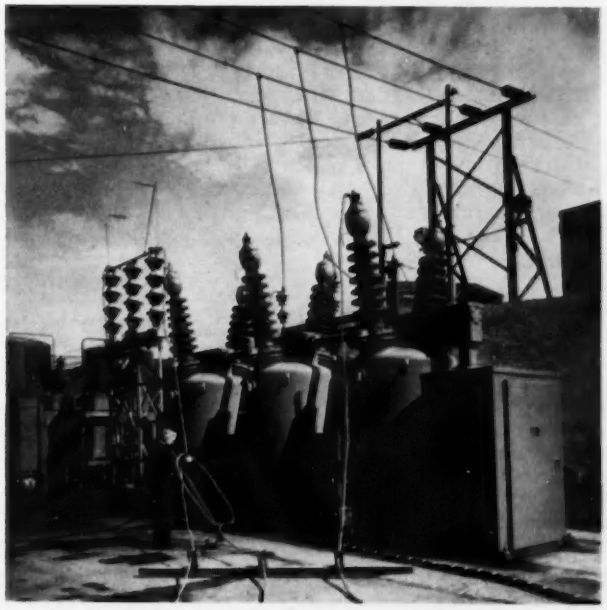


Fig. 2.—5,000 MVA oil circuit breaker undergoing tests at the High Power Testing Laboratory.

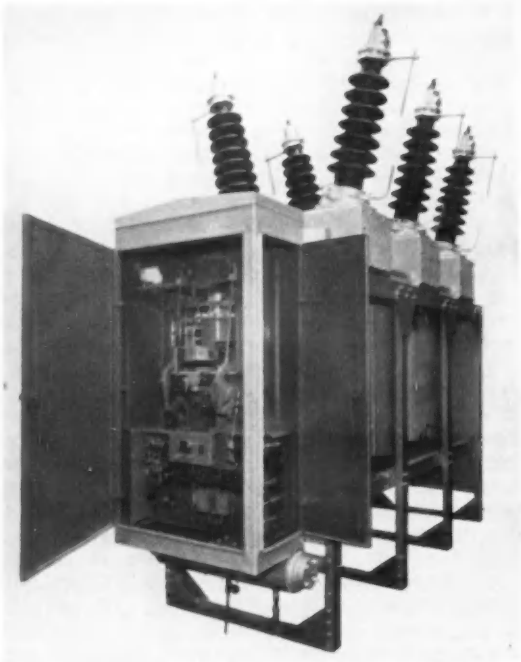


Fig. 3.—Compressed air operating gear on a 66 kV outdoor oil circuit breaker.

Rules No. 15, with a recovery voltage of 130 per cent. of the rated phase voltage. Fig. 2 shows the circuit breaker under test at the High Power Testing Laboratory.

A further series of supplementary tests was carried out which, by special arrangement with the Central Electricity Authority, included line-dropping tests on a section of the 132 kV grid line which passes close to the Witton High Power Testing Laboratory. Various lengths of line were disconnected by the breaker, involving charging currents up to 75 A. During the course of more than a hundred interruptions, the line over-voltage factor did not exceed 1·8.

Tests involving the interruption of small inductive currents down to 20 A at low power factor, and transformer magnetising currents between 30 and 60 A produced no over-voltages in excess of the inherent restriking transient.

Other tests carried out successfully included over-capacity interruptions at 5,600 MVA ; a high-speed reclosing cycle on a 5,000 MVA short circuit consisting of : break—22 cycles—make-break—3 minutes—make-break ; an out-of-synchronism duty cycle of : make-break—3 minutes—make-break, at twice the rated voltage and 40 per cent. of the rated breaking capacity ; and a three-phase single-pole test (Biermans Test) in which the maximum available energy from the test-plant was released into one tank.

Another new development is the introduction of a range of compressed-air drives for use with the majority of G.E.C. outdoor circuit breakers. Breakers fitted with these drives for 132 kV and 66 kV are nearing completion to the order of the Uttar Pradesh Government in India ; one of the 66 kV units is shown in fig. 3.

The essential difference between the pneumatic drive and a conventional solenoid drive is the replacement of the closing solenoid by a cylinder containing a piston actuated by compressed air. A closing operation is initiated by operation of an electro-pneumatic control valve which admits compressed air to the cylinder. All components in contact with the compressed air are made from non-ferrous metals and are thus unaffected by the presence of incidental moisture.

The remainder of the mechanism remains substantially unchanged, apart from the provision of a compressor either for each breaker, or, more usually, common to all the breakers in a station. In the latter system, air is compressed to 250 p.s.i.g. by a two-stage compressor which feeds the station high-pressure storage receiver. By means of a reducing valve, the pressure is reduced to 150 p.s.i.g. and delivered through piping to local air receivers mounted adjacent to the breaker mechanisms. Sufficient air for four closing operations is stored in the local

Fig. 4.—33 kV, 750 MVA metalclad switchboard for Kuwait.

receivers and interlocks are provided which prevent operation at less than the prescribed pressure.

Of the many contracts received for outdoor oil circuit breakers, that for a new switching station to be erected near Wolverhampton is deserving of mention. It includes 132 kV, 3,500 MVA oil circuit breakers for a 17-switch section and 275 kV, 7,500 MVA breakers of the air-blast type for a 3-switch section, the latter being built under sub-contract by A. Reyrolle & Co. Ltd. At associated substations in the vicinity, 23 oil circuit breakers installed by the Company as part of the original grid system are to be modified to increase their breaking capacity from 1,500 MVA to 2,500 MVA.

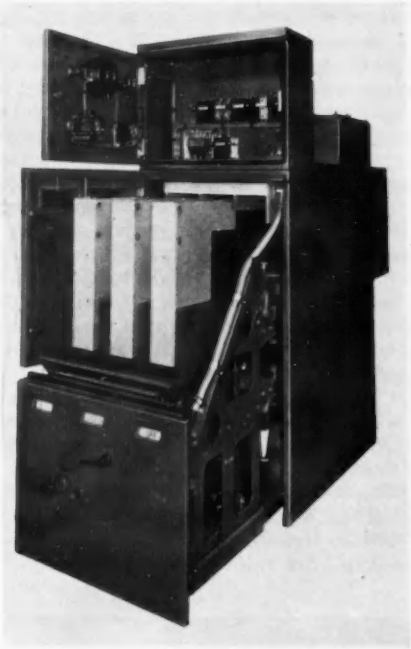


Fig. 5.—New design of 3·3 kV air circuit breaker.

For service in India, equipment comprising three 66 kV and ten 22 kV oil circuit breakers is being built for the Bombay Electricity Board, and ten 33 kV breakers are in hand for the Government of Bihar, Patna.

INDOOR SWITCHGEAR.

Reference was made last year to the order for a 33 kV switchboard for installation in Kuwait. This board has now been completed and is illustrated in fig. 4. The circuit breakers are rated at 33 kV, 750 MVA, and the switchboard is of the fully phase-segregated pattern, with duplicate busbars. This gear has been conservatively rated to allow for the very severe operating conditions obtaining in Kuwait. Other 33 kV switchgear of this type is being supplied to Brisbane City Council for Tennyson Power Station, but here the circuit breakers are rated at 1,000 MVA.

The existing G.E.C. range of medium-duty metal-clad gear has been extensively modernised and restyled, so as to conform with standardised manufacturing techniques already adopted for metalclad gear of other ratings. An eleven-panel switchboard of the new design for Colvilles Ltd., with circuit breakers rated at 11 kV, 350 MVA, has recently been installed.

A 3·3 kV air circuit breaker for indoor service has been developed and is now in production (fig. 5). It has been designed for controlling power station auxiliaries and similar applications. Two sizes are available, with normal current ratings of 1,200 and 2,000 A. The design is modern in conception and represents the latest practice for this class of switchgear. Special care has been taken to ensure ready accessibility. Isolation and earthing switches are mounted integrally with the breaker on a withdrawable truck so that all interlocks and parts liable to require maintenance are brought together on a single removable unit.

The arc chutes are of the metal splitter type without blow-out coils, arc extinction at low current values being assisted by an auxiliary air puffer. The standard G.E.C. method of construction using folded sheet-steel is used for the cubicles, which are generally similar in appearance to those for low-voltage air-break gear.

Comprehensive short-circuit tests, including interruptions over a range from 10 A to 15 per cent. above the rated breaking capacity, have been successfully carried out on these breakers, and an A.S.T.A. certificate has been issued for a rating of 150 MVA. Developments are in hand for increasing this to 250 MVA. Heat runs have shown that the current-

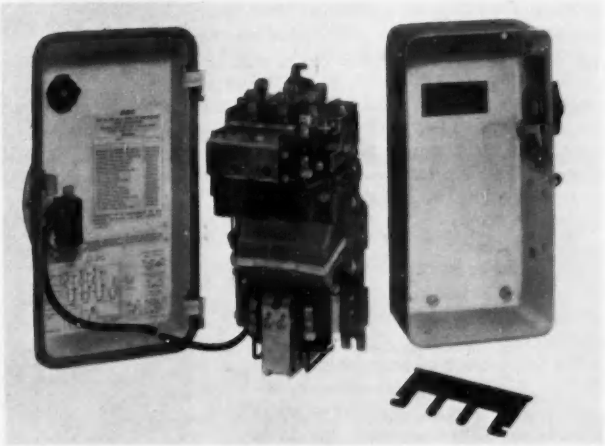


Fig. 6.—7½ h.p. vertical lift direct-to-line starter removed from its case.

Fig. 7.—New design of motor control centre.

carrying capacity of the equipment is more than adequate for the ratings assigned.

INDUSTRIAL AND DOMESTIC SWITCH AND FUSE GEAR.

A completely new range of vertical-lift contactors and direct-to-line non-reversing starters has recently gone into production. This equipment incorporates innovations both in materials and design, combining robustness and accessibility with an attractive appearance.

Two sizes of contactor are being manufactured, rated at 25 and 50 A respectively. These contactors also form the main components of the direct-to-line starters, which cover a complete series of ratings up to 30 h.p. and 600 V.

Fig. 6 shows a 7½ h.p. starter removed from its case by unscrewing the three retaining bolts. The contactor, with vertical-lift armature and arcing chamber, is surmounted by an interrupter switch, which takes the place of the usual isolator, together with three dashpot-type overload trips. The armature guide is treated with molybdenum disulphide to reduce wear ; mechanical tests including runs of ten million consecutive switching operations on individual starters have demonstrated the ability of the equipment to withstand arduous working conditions over a long period.

The arcing chamber of the contactor is moulded in a mineral-filled Alkyd material which is notable for its excellent arc-resisting and non-tracking properties. Separate moulded Alkyd arcing chambers are also used for each phase of the interrupter switch, which is capable of interrupting currents in excess of the contactor breaking capacity. This means that in addition to providing isolation of the starter for normal maintenance, the interrupter can be used in emergency to disconnect the motor from the supply.

The successful design and manufacture of the motor control centres now installed at the Esso Refinery at Fawley has led to further development work aimed at providing alternative features to meet the requirements of a wider circle of users. Features of the new design (fig. 7) include the substitution of isolating switches and H.R.C. fuses for the small feeder circuit breakers used on the original boards and the provision of start and stop buttons and ammeters mounted in the cubicles.

An individual cubicle will accommodate six 12½ h.p., four 30 h.p., three 50 h.p., or two 100 h.p. D.T.L. starters, or combinations of these at voltages up to 600. Other assemblies such as fuse distribution panels and switch-fuse units are also available. Chambers are provided at the top and bottom of each cubicle for main busbars and cable-entry fittings respectively. If cable entry is required at the top,

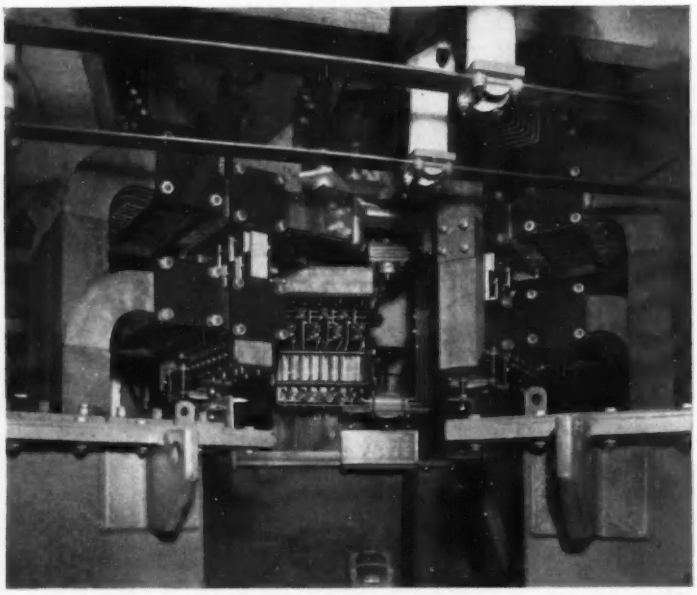


Fig. 8.—Switching links on secondary windings of heavy current test transformer.

the busbars are accommodated in the lower chamber, and vice versa.

Apparatus units are plugged on to vertical bars mounted at the rear of each cubicle. These bars are connected to the main horizontal busbars. Outgoing cables are carried in a cable duct on the right hand side of the cubicle. All operation and maintenance is effected from the front and cubicle doors are interlocked to prevent their being opened unless the isolating switches are in the "off" position.

A three-phase low-voltage oil circuit breaker with a current rating of 150 A and breaking capacities up to 5 MVA has been added to the range of industrial gear. The breaker can be supplied either mounted on a pedestal or for installation in conjunction with panel-pack switchfuse gear. An interlocked isolating switch can be fitted if required, and space is provided for back-up H.R.C. fuses, which can be used to increase the overall breaking capacity up to 35 MVA.

A comprehensive range of H.R.C. cartridge fuses for normal current ratings up to 800 A is now available. A.S.T.A. certificates have been issued for ratings from 2 to 600 A in category of duty 550 A.C.5, B.S. 88 : 1952 ; and from 650 to 800 A in category 440 A.C.5. The direct current category 500 D.C.4 has also been assigned to fuses up to 300 A normal current following the completion of satisfactory tests.

Tests have recently been satisfactorily carried out in accordance with specifications of the Canadian Standards Association, for ratings up to 600 A.

High-voltage fuses for voltages of 3·3, 6·6, 11 and 33 kV with three-phase breaking capacities in accordance with B.S. 2692 : 1956 are also available. This range includes both power fuses and voltage transformer fuses.

PROTECTIVE GEAR.

A description was given last year of a comprehensive equipment for delayed automatic reclosure in a 132 kV single switch substation at Daventry. During its first twelve months of service, the equipment has been called upon to operate three times. A further equipment is now being installed on the feeders of a 132 kV ring substation at Stafford.

Development of new forms of apparatus in connection with protective gear has proceeded steadily. A new auto-reclose relay has been produced to provide high-speed initial reclosing of oil circuit breakers fitted with spring-closed mechanisms. The relay consists essentially of a flux decay type timer with an adjustable delay calibrated in cycles. It may be used alone as a single-shot high-speed recloser or, in conjunction with a standard timer, as a multi-shot recloser. In the latter application, the first reclosure takes place at high speed and the predetermined number of subsequent shots is effected as soon as the mechanism has been recharged by the automatic spring charging motor.

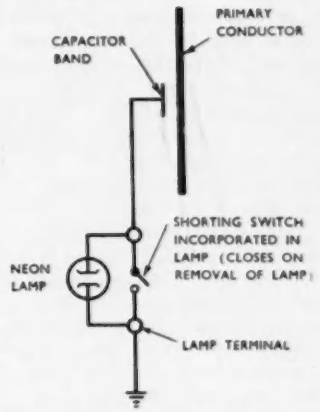


Fig. 10.—Neon potential indicator.

A new type of neon potential indicator (fig. 10) is now available for control-panel mounting. The indicator has been adapted from the standard switchboard indicating lamp body and is fitted with a neon lamp, together with a shorting switch which earths the capacitor band on removal of the lamp.

EXTENSION OF HEAVY CURRENT TEST PLANT.

The first section of a new heavy current test plant in the Switchgear Works was completed some two years ago and was referred to in a previous review of progress.* This section, with an output of 15 kA, has now been supplemented by the installation of the second and final stage of the plant. The new section is capable of supplying alternating currents of up to 44 kA at low power factor with an open-circuit

* *G.E.C. Journal*, Vol. 21, pp. 15-16, January, 1954.

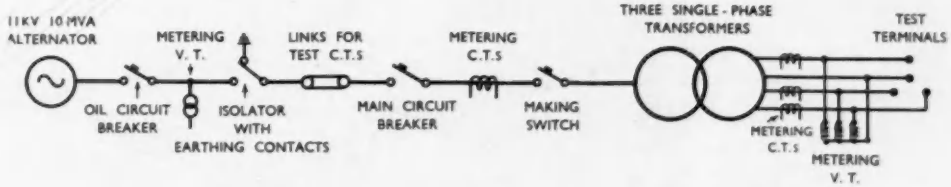


Fig. 9.—Simplified single line diagram of the new section of the heavy current test plant.

voltage of 100 volts, the general layout being shown in the single-line diagram (fig. 9).

The 11 kV supply from the alternator is stepped down by three single-phase transformers to give a continuously variable voltage from 10 to 700 volts at the test terminals. This fine adjustment is made possible by an elaborate system of series and parallel switching of sections of the transformer secondaries in both star and delta (fig. 8) in conjunction with adjustment of the alternator excitation.

The plant is controlled from a desk situated conveniently near to the test-beds, and accurate switching sequences are obtainable with the aid of a point-on-wave switching device and sequence control relay. Cathode ray and electromagnetic oscillographs, together with chokes and resistors for current and power-factor control, are common to both the existing and new sections of the plant, and a darkroom is provided for oscillogram processing.

The new section has widened the scope of the test plant considerably. In addition to tests on protective gear, it is now possible to carry out tests of breaking-capacity, heating, and mechanical strength on a variety of switchgear and fusegear. The 15 kA section continues to be used for routine tests and development work on protective gear.

CABLES.

The growing application of oil-filled cables has been reflected in orders received during the year. The first 330 kV oil-filled cables to be made in this country are being manufactured by Pirelli-General Cable Works Ltd. at Eastleigh for the Snowy Mountains Hydro-Electric Scheme in New South Wales, the contract having been received through The British General Electric Co. (Pty.) Ltd., of Sydney. It comprises the manufacture in England and the installation in Australia of approximately 3,500 yards of 330 kV single core ·325 sq. in. copper conductor oil-filled lead-sheathed cable for the T.1 power station in the Tumut River valley. Seven single-phase cables for 340 amp will be grouped in two three-phase circuits with one spare cable and will be supplied complete with terminations, supporting structures and all ancillary equipment.

The Snowy Mountains Scheme is the largest project in the Australian programme of development works and is estimated to cost over £A.400 million. The region covered by this vast scheme is one of the wildest in Australia and lies within the Australian South Eastern Highlands of New South Wales.

Engineers have recently completed the installation in British Columbia of further oil-filled cable for the Kemano-Kitimat project of the Aluminium Company of Canada. An order for three lengths, totalling approximately 6,000 ft., was received through The British General Electric Co. (Canadian) Ltd., the cable being required for a new three-phase circuit to handle additional power between the subterranean power-house at Kemano and the termination of the overhead line to the electrolytic tinning plant at Kitimat, 50 miles away. As in the previous installation,* the cables will run through a 670-yard-long tunnel between the power house and the overhead line termination.

At home, orders are in hand for the manufacture and installation of three-core 132 kV oil-filled cables for the Yorkshire, Eastern and Southern Divisions of the Central Electricity Authority.

* *G.E.C. Journal*, Vol. 22, pp. 166-171, July, 1955.

Considerable progress has been made at the Witton Moulded Insulation Works in mechanical aids to production and in the mechanisation of finishing and assembly processes. This illustration shows a multi-loading device for assembly of terminal screws in strip connectors.

The Year's Progress

Instrumentation

AUTOMATION.

When a trend long evident in industry is given a name, it is as tempting to stretch the definition to cover processes for which it was not intended as it is easy to overlook familiar methods which might well be so described. The G.E.C. has already supplied items of equipment over a number of years which fall within the field generally known as "automation". Arrangements have now been entered into with the British Tabulating Machine Co. Ltd. for setting up a development company to design high-speed digital computers of advanced types. Data processing by these methods is the foundation of production control. The new company is known as Computer Developments Ltd.

The new organisation will cover the whole field of application of computers. By reason of its work in other directions, the G.E.C. is equipped already with a fund of practical experience. Simulators have been designed for reproducing complex full-scale conditions and the knowledge so gained is applicable to all problems involving the handling of many variables.

In computing equipment it is often necessary to store a pulse train for a limited time and development has been taking place in ultrasonic delay lines for this purpose. A new type has been designed with advantages in size and independence of temperature which provides a precisely-timed delay of a few microseconds.

At several exhibitions during the year interest has been created by the display of a "noughts and crosses machine" made by Salford Electrical Instruments Ltd. which wins or draws in every game against a human player. It is operated by depressing small panels in the places where the player would normally make his cross. His move is registered in the "brain", or dictionary of the machine, which replies by marking a nought in the centre square, or in the top left hand square if the centre is occupied. Subsequently the machine selects a tactical or defence move until the game is won or drawn. All the processes of studying the opponent's moves and selecting the appropriate replies are effected through 36 double-wound P.O. relays with a total of 270 contacts. A relay type dictionary of this kind might be applied to controlling the programme of operation of a machine tool or to weaving in different patterns. While similar effects could be obtained with uniselectors, this would involve using two uniselectors each with ten banks of 50 contacts.

The scanning of conditions and the application of data to the control of processes is seen in many forms. This principle will be used in the control of three main groups of lifts to be installed by The Express Lift Co. Ltd. at Bucklersbury House, the largest and highest building now being erected in London. An automatic supervisory system will be installed, whereby the operation of the lifts in each group will be concentrated in the direction of the heavier traffic. Well-defined peak periods will occur in the morning when people are arriving, during the midday lunch break, and in the evening when people are returning home. Sometimes, too, minor peaks will occur. All such fluctuating traffic conditions will be taken into account and the lifts will be arranged to operate to and from the floors where the traffic is heaviest at any time.

During these peak periods, the building will be divided into two zones—high and low. The line of demarcation between the high and low zones can be adjusted should the traffic situation warrant it. The lifts in each group will also be divided so that some will serve the low zone and the others the high zone, thus markedly decreasing round-trip time by reducing the number of stops for each car. The master controller will be sensitive to varying traffic conditions, and will control the supervisory system so as to make automatic adjustment of despatch intervals and ensure equalisation of the lift service between high and low zones. During the less busy periods the number of cars in service will be reduced in accordance with traffic demands.

Automatic monitoring of production processes is complementary to automation in its various forms since reducing human supervision gives greater importance to means of detecting faults. At a tobacco factory the problem arose of detecting the presence of small metallic objects in tobacco passing through an aperture measuring 15 in. by 8 in. An oscillator is connected to two coils below the aperture which are arranged to produce equal and opposite fields in a third coil above the aperture. The third coil is connected to a sensing amplifier and alarm. The presence of a metallic object as small as a $\frac{1}{8}$ in. ball bearing is sufficient to distort the fields so that a current pulse is induced in the third coil to operate the alarm.

ALTITUDE MEASUREMENT.

While new requirements often call for the application to measurement problems of techniques which may have had an origin unassociated with instrumentation, there are also cases where new methods applied to familiar forms of measurement bring a far higher degree of accuracy and certainty than has been possible before. In the air the compass and the altimeter have always been the essential instruments of navigation but the fact that the aneroid altimeter measures height above sea level, and must be set in accordance with the prevailing barometric pressure, adds to the calculations

and allowances which the navigator has to make. Various electronic systems have been developed in recent years for giving a direct indication of height above ground (terrain clearance), and in a new radio altimeter now in quantity production (fig. 1) this is accomplished by a frequency-modulation system.

The G.E.C. radio altimeter gives a precise indication of the height of the aircraft above ground from 0 to 5,000 ft., with cyclometer type presentation for units of thousands of feet and a pointer reading continuously between the zero and 1,000 ft. markings on a complete circular scale.

Signals are radiated continuously by a U.H.F. oscillator which sweeps at a known speed through a band of 50 Mc/s. The difference in frequency between an echo received at the aircraft and the frequency of the transmitter at that instant is a measure of the altitude and is converted into an I.F. signal for amplification in a double-superheterodyne receiver, being finally detected to an A.F. output suitable for operating the indicating devices. Automatic control is applied to the transmitting oscillator so that the beat frequency produced with the echo signal does not exceed 10 kc/s at any altitude within the range of the instrument, and the consequent restriction of the required A.F. bandwidth in the receiver minimises noise.

The scale and pointer indications are supplemented by light signals which can be pre-set by the pilot so that a green light shows when he is flying within plus or minus 15 ft. of his chosen height above the ground, with red and amber signals respectively if he descends below or climbs above these limits. A power supply failure causes simultaneous display of the red and amber lamps.

The altimeter is supplied through a power unit (fig. 2) operating on the aircraft 24 volt d.c. system giving a 19·5 volt d.c. output stabilised by a carbon pile voltage regulator and 250 volts H.T. from a rotary transformer. Aerials are two small dipoles normally mounted in reflectors which fit flush with the aircraft skin. On certain aircraft it is possible to use the aerials as open dipoles bolted to the skin.

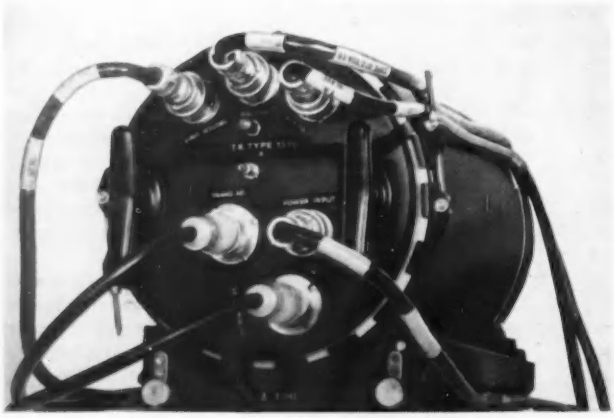


Fig. 1.—Transmitter/receiver unit of radio altimeter.

AERIAL PHOTOGRAPHY.

A number of important developments are in progress in connection with aerial photography. Hitherto exposures for aerial photographs have had to be fairly short because of the relative movement of the image and the lens while the shutter is open. This has necessitated the use of a coarse-grain film, involving some loss of detail when small features are greatly enlarged for examination. If the film is moved during the exposure at a speed corresponding to the apparent movement of the object, exposures can be longer and a fine-grain film can be used. Initial experiments were made by modifying a standard R.A.F. camera mounting so that the whole instrument could swing in the direction necessary to compensate for relative movement during exposure. The next step was

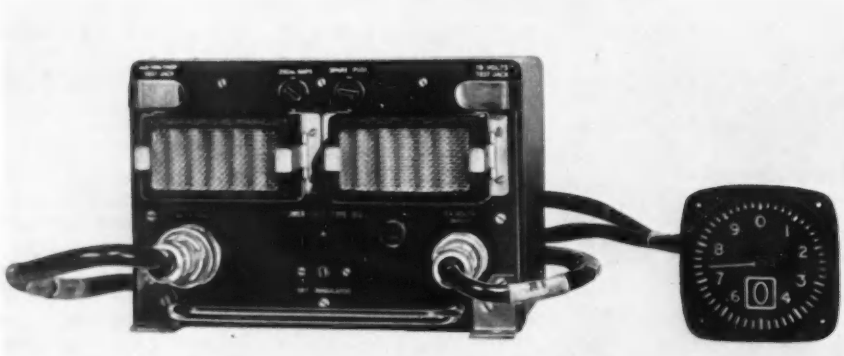


Fig. 2.—Radio altimeter power unit and indicator.

the introduction of a moving film register plate to produce the same effect without swinging the camera. Two or three rates of movement of the register could be selected. From this stage a continuously variable control of register plate movement has been developed, automatically effected by setting a computer for height and groundspeed. These improvements have been accompanied by the introduction of a gyroscopic camera mounting to compensate for aircraft angular movements during exposure of the film. Provision is made for turning the camera about its axis during flight to different angular settings so that the image movement compensation may take place in the right direction even when the aircraft is drifting sideways under the influence of crosswinds. A new camera incorporating these developments has been designed (fig. 4) and has the additional interesting feature of being arranged to take daylight-loading film cassettes. An example of photography with the camera is shown in fig. 3.

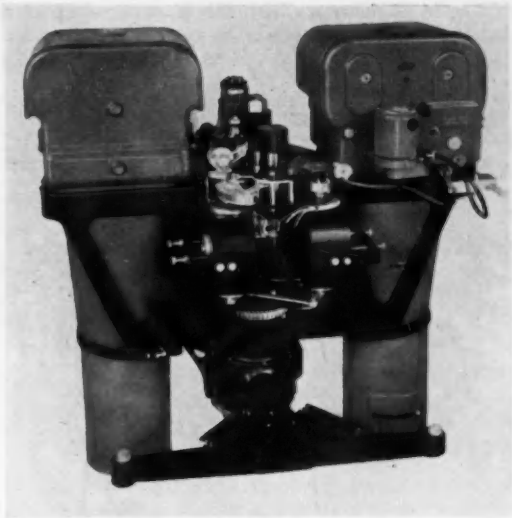


Fig. 4.—Aerial camera with moving film register plate and gyroscopic mounting.

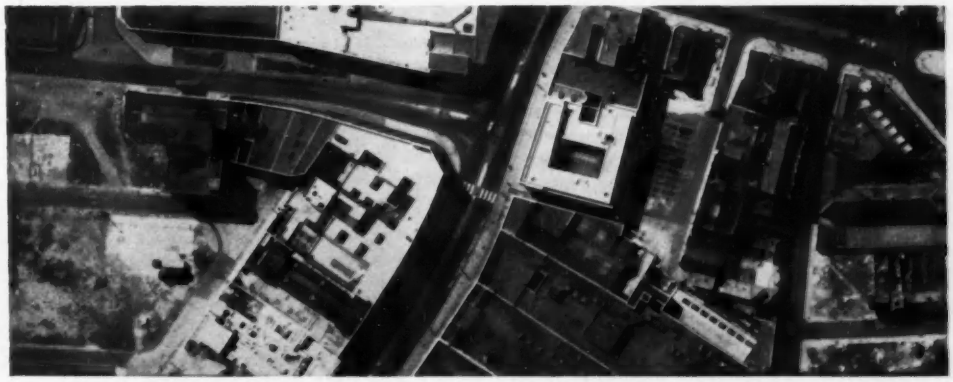


Fig. 3.—Enlargement of part of an aerial photograph, showing the definition obtained when using the moving film register plate.

TRANSDUCERS.

Applications of transducers for the remote indications of various quantities are increasing. At the C.E.A. Marchwood power station they are in use for the operation of steam pressure and fuel oil pressure gauges on remote meter panels so that the operation of the plant can be under centralised supervision. A further interesting application is the use of transducers in connection with recording water pressures on the hulls of flying boats in a test tank at Saunders-Roe Ltd.

In general instrumentation practice, the deposition of selenium on aluminium by a vacuum process has facilitated the production of instrument rectifiers with a very low capacitance.

Barium titanate accelerometers are finding numerous applications in place of magnetic pick-ups for many forms of industrial vibration measurement and detection and for purposes such as shock readings of packaging materials and drop tests. There has been similarly comprehensive development in the use of barium titanate strain gauges, both for measurement purposes and for exciting vibrations in plates and solid beams.

PHOTO-ELECTRIC EQUIPMENT.

With the increasing interest in smoke abatement and the tightening of restrictions on atmospheric pollution, means for detecting and recording smoke in chimney stacks become of increasing importance. Photo-electric equipment is ideal for this duty and is now being used extensively in conjunction with chart recorders and alarm systems. The equipment complies with British Standard No. 2740. It is constructed to permit a continuous small flow of clean air across the projector and receiver glasses, which are mounted in slides to simplify cleaning.

Oil-firing of boiler plant and furnaces is rapidly

gaining in popularity. With this plant it is important that the fuel supply should be cut off promptly and

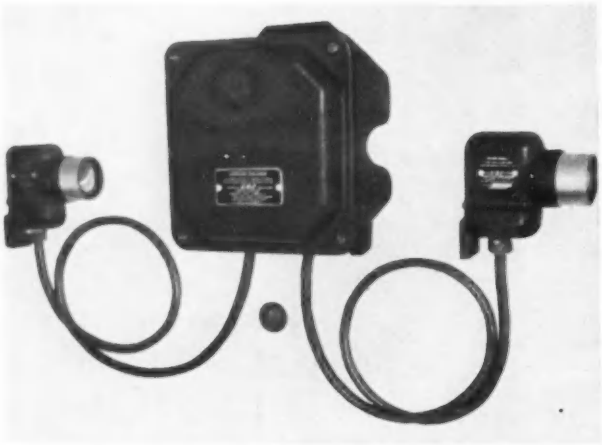


Fig. 5.—Flame monitor equipment for oil-fired furnaces.

automatically in the event of flame failure. For this duty a flame monitor (fig. 5) has been developed. It consists of two units—an antimony photocell with amplifying valve and a relay which initiates the cutting-off of the oil supply. The relay is mounted in a separate housing, together with the amplifier transformer which feeds the photo cell and valve. False indication from the luminance of the firebox cannot occur because the antimony photocell is insensitive to infra-red light. A glass heat filter embodied in the equipment prevents heat from reaching the photocell.

The daylight monitor, which initiates the switching-on of artificial lighting automatically when the daylight falls below a predetermined level, has been improved to provide greater reliability in operation. This has been achieved by simplifying the control circuit and at the same time production costs have been reduced.

Further developments in the design of short, medium and long range projectors have simplified alignment of the light beam and improved the external appearance of the apparatus; a projector for short-range duty is shown in fig. 6.

Photo-electric equipment has now been accepted as the means of protecting operators of heavy power presses. A " fence " of light beams projected across the front of a press can be arranged to switch off the power and brake the machine almost instantaneously if interrupted by the operator's hand or part of his person. Regulation guards, of course, are required above and below the area covered by the beams, but the use of a light "curtain" obviates the necessity of opening and closing a mechanical guard and thus improves production efficiency. It also obviates the interlocking necessary with a mechanical gate and the mechanical drive required in large installations.

The G.E.C. electronic press guard equipment complies fully with the recommendations of the Joint Standing Committee on fencing of press brakes given in the report of the Factory Department of the Ministry of Labour and National Service. In its usual form eight light beams are projected across the area to be screened. These fall on photocells linked with a valve amplifier which operates telephone type relays. Interruption of the " curtain " by the standard test bar actuates the press braking mechanism to protect the operator. The guard is designed to fail to safety in the event of the failure of expendable components, and a checking device is provided to ensure that the unit is in working order before each down stroke of the slide.

Fig. 6 —Short range projector.

Transport

ELECTRIC RAILWAY TRACTION.

Last March the British Transport Commission announced its decision to adopt single-phase a.c, at 25 kV, 50 c/s, for future railway electrification in Great Britain, outside certain areas where existing systems will be continued. For the electrification on the high-voltage a.c. system of the Eastern Region main line from Liverpool Street to Bishop's Stortford and the branches to Enfield and Chingford, the G.E.C. is to supply the traction equipment for 70 three-coach multiple-unit trains. Each will consist of a driving trailer, motor coach and second driving trailer. The motor coach power equipment will be mounted on the underframe, while the battery, battery charging equipment and compressor will be carried on the underframe of the second driving trailer. The transformer, the switchgear for series or parallel connection of the primary for operation on 25 kV or 6·6 kV and the tap changer in the secondary circuit will form a single assembly with cooling by forced oil circulation. The alternating current will be rectified by a group of single-anode rectifiers, the d.c. output from which will be smoothed by air-cooled chokes and fed to four 200 h.p. (1-hour) traction motors. Class H (silicone) insulation will be used for the traction motors and smoothing chokes.

Fig. 1.—New 300 A power receptacle.

While the use of 25 kV at 50 c/s for traction is new in this country, 6·6 kV electrification at 25 c/s had covered a considerable area in the London area of the former Southern Railway by the time it was abandoned for d.c. in 1929. The G.E.C. thus acquired early manufacturing and operating experience with a.c. equipment, having supplied the control gear and motors for 21 Southern Railway motor bogie vans which were built for this system after the first World War.

Electrical equipments for thirty-two 4-coach trains of the semi-express, limited stop type for the Liverpool Street to Southend line in the Eastern Region of British Railways, were completed during the year and the rolling-stock began service to Southend on December 31, after certain units had completed several months' running to and from Chelmsford.

For the fifty-seven new 3-coach multiple unit trains which will replace the existing rolling-stock on the Euston-Watford service, a new 300 amp power receptacle and jumper has been developed (fig. 1). Also for use on these trains, a new design of shoe gear (fig. 2) has been produced with the object of improving current collection, reducing wear and eliminating the noise emitted by normal types of gravity shoe gear when not in contact with the conductor rail. Rubber is used both as a noise damping and springing medium, Andre-Neidhardt units being employed at the joints of the links, which are arranged

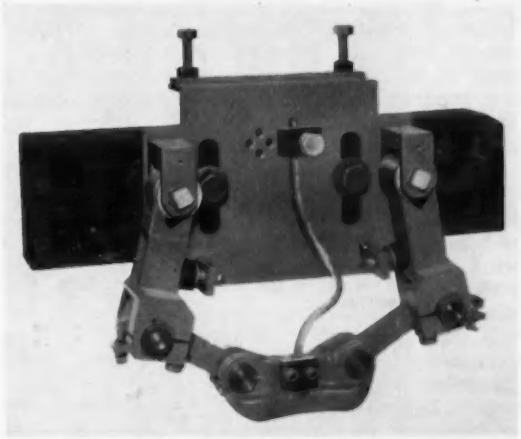


Fig. 2.—Shoe gear using rubber as a noise-damping and springing medium.

to rest on rubber cushions when in the released position.

Motors ordered by the London Transport Executive for three prototype tube trains have been delivered. This contract covered 32 machines with a continuous rating of 80 h.p.* Investigations have been made at the request of the Executive into the feasibility of applying regenerative braking in tube trains with the object of (1) reducing the heat dissipated by the mechanical brakes and consequently the rise in air temperature in the tunnels, (2) reducing wear on the brake blocks, and (3) saving energy consumption.

Two experimental regenerative equipments are being supplied to the L.T.E. and running trials will begin in the near future. Although as much standard apparatus has been used as possible, the control scheme involved certain new designs and modifications. Of these the shunt field control group is of particular interest. It is an adaptation of the standard field control group as used in diesel-electric equipments. The segments of a fixed commutator are connected to the shunt field resistances and the brushgear is rotated by a pneumatic engine which is controlled by electro-pneumatic valves. Hydraulic damping ensures smooth and easily-controlled movement of the brushgear.

Resulting from prolonged development work both in the Company's Witton Works and in South Africa, a new design of 3,000 volt d.c. surge diverter has been produced to meet the specific requirements of the South African Railways. Nine of these diverters are being supplied for fitting to the 3,000 h.p. class "4E" locomotives which are in service on the main line between Cape Town and Touws River.† The diverter, which comprises a silicon-carbide non-linear resistor, spark gap and permanent magnet blowout, is designed to limit any surge voltage to 7 kV with surge currents up to 10 kA.

DIESEL-ELECTRIC TRACTION.

The satisfactory performance of the fifteen diesel-electric shunting locomotives for the North Eastern Region of British Railways has resulted in another contract being placed for a further forty-five equipments of the same design.‡ It will be recalled that each comprises a 350 h.p. Blackstone diesel engine direct-coupled to a generator which supplies two axle-hung double-reduction-geared traction motors.

Equipment is in course of construction for ten 1,000 h.p. main-line and ten 800 h.p. branch-line diesel-electric locomotives for British Railways being built in conjunction with the North British Locomotive Co. Ltd. An interesting development in these locomotives is an improved system of motor field control whereby transitions from full to weak field both forward and backward on any engine power notch are made automatically, thereby ensuring the utmost utilisation of engine power over a very wide range of locomotive speeds.

* *G.E.C. Journal*, Vol. 23, p. 40, January, 1956.
† *G.E.C. Journal*, Vol. 20, pp. 109-126, April, 1953.
‡ *G.E.C. Journal*, Vol. 22, pp. 209-218, October, 1955.

Problems associated with commutation on the high speed, high output machines now being built have received careful study. The 1,500 r.p.m. main generators for the above 1,000 h.p. main-line locomotives presented unusual commutation difficulties which called for exhaustive study before a suitable design of machine was evolved. Improved types of brushgear have been developed to ensure stable operation, particularly where split brushes are used.

DEVELOPMENT.

During the past year efforts have been concentrated on investigating means to increase the outputs of traction machines. New methods of insulation have been developed, particularly for machines in the medium-voltage range for diesel-electric locomotives. As a result the transfer of heat from the windings to the cooling air has been much improved, giving a corresponding higher output for the same temperature rise. This is further assisted by improved forms of construction which give a better winding space factor.

Full consideration has also been given to the advantages to be gained from class H insulation, which permits operating temperatures above the limits imposed by class B insulation. Four motors with class H insulation have been in service for the past three years in London Transport Executive "R" stock motor coaches and have been subjected to increased temperature rise by restricting the air flow to a very small amount. Their performance has been fully satisfactory, and now that Class H insulation is becoming more readily available its use on traction motors will undoubtedly increase.

Comprehensive investigations into the factors influencing bogie construction are in progress. A study has also been made of the adhesive qualities of locomotives powered by motors connected in different ways with various systems of control. From this investigation much useful knowledge has been gained on the limitations imposed by adhesion on the performance of a locomotive.

CABLES.

The British Transport Commission's decision to adopt the 50 c/s single-phase system at 25 kV for general main-line electrification on British Railways will involve the provision of overhead contact line equipment on a far wider scale than has been seen previously in this country. On d.c. railways, also, voltages of 1,500 or 3,000 volts with overhead supply are usual in new work, while main lines with conductor rail systems may require overhead equipment in sidings and marshalling yards as goods traffic is handed over progressively to electric traction. A special section has therefore been formed in the Overhead Lines Department of Pirelli-General Cable Works Ltd. at Eastleigh which will be responsible for overhead traction equipment for railway electrification.

The section will shortly be prepared to deal with

complete electrification schemes, from the preparation of initial track layouts to the final installation of the overhead equipment. The work will include the design, manufacture and erection of supporting structures, catenaries and contact wires, fittings, section switches and insulators, track and structure bonds.

A recently completed agreement between Pirelli-General and Brown, Boveri & Cie, of Mannheim, will result in the free exchange of technical information between the two Companies. Brown, Boveri & Cie are one of the pioneers of railway electrification, and experience gained by them in many parts of the world will be placed at the disposal of Pirelli-General engineers. Their experience is, of course, most extensive in connection with contact line work for high-voltage a.c. electrification as now adopted by the British Transport Commission.

The first installation of oil-filled cables on British Railways is due to be completed this year with the bringing into use of a ring main system for supplying Southern Region substations in the London suburban area with power from the C.E.A. grid. Over 260 miles of 33 kV cable are being supplied and laid, together with 6 miles of 66 kV oil-filled and 19 miles of 11 kV and 33 kV solid type cables. An experimental length of some three miles of 33 kV oil-filled cable with aluminium sheathing has been laid between Wimbledon and St. Helier substations (fig. 3). These installations are in connection with the Southern Region change-of-frequency scheme and have been accompanied by the provision of pilot supervisory star quad telephone cables totalling 230 miles for the remote control of substations.*

RAILWAY SIGNALLING.

During the year the Siemens and General Electric Railway Signal Co. Ltd. has completed the modification of signalling on the Shenfield-Chelmsford and Shenfield-Southend (Victoria) extensions of the Eastern Region 1,500 volt d.c. electrification, and the resignalling of some five miles of the steam-operated low-level suburban lines running east and west from Glasgow Central Station.† In the Glasgow installation the need for detonator placers where the view of signals may be hindered by smoke and steam has been met by modifying the Company's standard type LT signal machine (fig. 4). The machines, of which twenty-two have been installed for this purpose, are operated on the 110 volt a.c. signalling supply through a transformer-rectifier unit housed inside the signal machine cases. Operation is entirely automatic, the detonators being lifted off the rail by the action of clearing the associated signal. A hold-off coil is energised to latch the mechanism against the effect of the balance weight when the detonators are clear of the track. Release of the latch by the signal being restored to " danger ", or in the event of an electrical failure, allows the weight to fall and replace the detonators on the rail.

As the British Railways modernisation plan progresses, S.G.E. is taking part in signalling schemes

* *G.E.C. Journal*, Vol. 23, pp. 137-151, July, 1955.
† *G.E.C. Journal*, Vol. 23, pp. 41–2, January, 1956.

Fig. 3.—Experimental length of aluminium-sheathed oil-filled 33 kV cable on the Southern Region, British Railways, showing cable joint and oil reservoir.

designed to expedite the handling of both freight and passenger traffic. An important contribution to freight movement will be made by the new marshalling

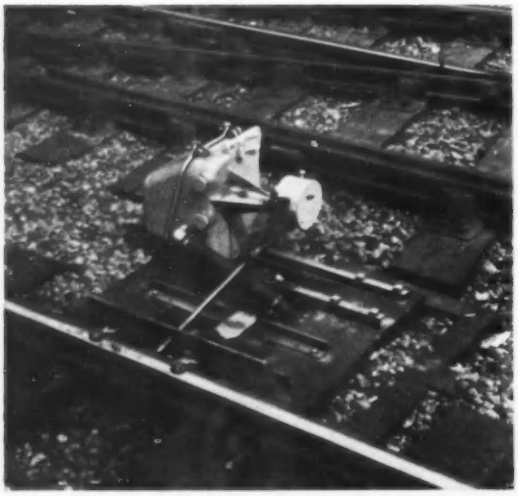


Fig. 4.—Modified signal machine in use as detonator-placer on low-level lines in Glasgow.

yard at Temple Mills, north of Stratford station on the Eastern Region, which will replace a group of ten out-of-date yards and make possible a general speed-up of freight traffic between London, East Anglia, the Midlands and North of England. It is estimated that this concentration of marshalling facilities will result in an annual operating economy of £150,000. The eastern approaches to the new yard will be controlled by an S.G.E. route-relay interlocking system of sixty-four routes, operated from a panel in a new signal box, Temple Mills East. Main signals will comprise seventeen of the multi-aspect type and three ground searchlights. Stencil and direction route indicators will be provided on certain signals. Points controlled from the panel will be worked by type HB electric machines combining operation and detection, and facing layouts will have ground tracklocks. In addition two mechanical ground frames will be installed and a 30-lever mechanical frame will be supplied and installed for the new Manor Yard signal box. Lever locks and circuit controllers will be provided for the mechanical signalling. The fifty-two track circuits will be d.c. so as to be immune from interference from the forthcoming single-phase a.c. traction system at 25 kV, 50 c/s, on the main lines through Stratford.

Overseas, the C.T.C. installation on the Livingstone line of the Rhodesia Railways is now in operation between Ngamo and Inyantue, covering seventy miles out of the 123 miles between Gwaai and Wankie which are being equipped with this system (fig. 5). The section most recently opened is that from Dett, where the control panel is situated, to Inyantue (sixteen miles). Power-operation of points controlled from the panel has been introduced on this section and is to be extended to the rest of the line between Inyantue and Wankie.

From the South African Railways a contract has been received for relay interlocking and automatic colour-light signalling on new lines serving native townships in the Germiston-Angus area of the Rand, east of Johannesburg. These lines will radiate from Ellsburg, and in the northerly direction will parallel for a short distance the existing lines to India and Germiston, although terminating at independent stations. Another section will run south-east from Germiston to a third new terminal station. A complete relay interlocking at Ellsburg will control the existing and new lines there, together with two of the new stations at distances of approximately five and two miles. This use of C.T.C. methods to effect remote control of relay interlocking at terminal stations on a double-track line handling heavy suburban passenger traffic will be an unusual and interesting feature of the installation. The third new station will be controlled remotely over a distance of about three-quarters of a mile through an existing power frame at India. Automatic signals will be installed on the new double-track lines and on one three-mile quadruple-track section formed by the new and existing lines running parallel with each other.

TROLLEYBUSES.

An order has been received through British United Traction Ltd. for the electrical equipment for 30 trolleybuses for Glasgow Corporation. Each will include a 125 h.p. motor and will use the Company's I.R. control system with rheostatic braking. The

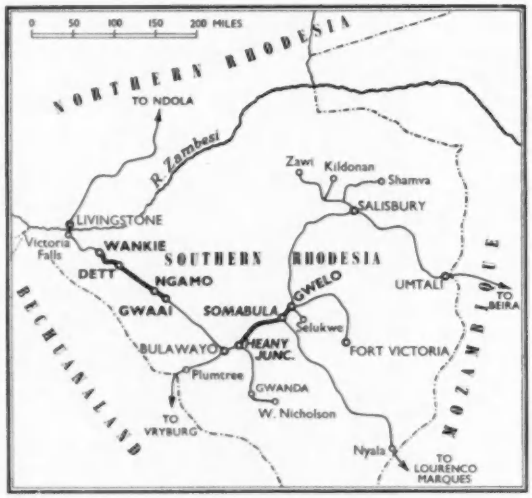


Fig. 5.—Sections of Rhodesia Railways on which S.G.E. Centralised Traffic Control equipment is operating or in course of installation (shown in bold lines and lettering).

controller provides for automatic acceleration under the combined control of an oil dashpot and current limit relay.

MARINE ELECTRICAL EQUIPMENT.

A contract has been received for two 2,000 s.h.p. diesel-electric propulsion equipments for two fish factory trawlers now being built by William Simons & Co. Ltd., for Christian Salvesen & Co. Ltd. Each main driving motor is a double armature machine driving a single screw and powered by three 530 kW, 400 volt diesel-driven generators. For full speed propulsion, all three generators are required, but on the fishing ground any one generator may be used to supply the twin-trawl winches.

Two sets of bridge control gear will be provided, one on the navigating bridge and one aft to facilitate manœuvring when shooting or hauling the nets.

In large fishing vessels of this type, the nets are hauled through a tunnel or ramp in the stern of the ship by twin trawl winches instead of the conventional arrangement in which the trawl warps are led from a single winch over the ship's side via two sheaves suspended from " gallows " forward and aft. The new arrangement confers obvious advantages in handling, particularly in avoiding the difficulties associated with drawing nets inboard in heavy weather.

The twin trawl winches are arranged one on each side of the vessel and are of particular interest. In order to haul or veer upon the two warps evenly, a speed tie is arranged between the winches, the control scheme being developed in close collaboration with the winch makers to ensure that the vital stalling and rendering characteristics are present under all conditions of operation.

Diesel-electric propulsion equipment is also in hand for a new pilot vessel for the Mersey Docks and Harbour Board, and will be similar to that already supplied for the Sir Thomas Brocklebank and Edmund Gardner of the same authority. The diesel-electric Royal Research Ship John Biscoe (frontispiece) sailed from Southampton on her maiden voyage to Antarctic waters on November 26.

In May the Bergensfjord of the Norwegian-America line was completed, the first British-built passenger ship to use a.c. for all auxiliary services. For tankers and ore carriers the a.c. system now predominates. Auxiliary installations for ships in these categories during the year have included two for vessels of 32,000 tons. One of these, the combined ore and oil carrier Ruth Lake of the Iron Ore Transport Co. Ltd., is a sister ship of the Sept Iles, which at the time of going into service at the end of 1955 was the largest ore carrier afloat and had a similar G.E.C. auxiliary installation to that of the Ruth Lake. The other 32,000 ton ship was the tanker Samuel Ugelstad of the S. Ugelstads Rederi A/S. A view of the main switchboard of this ship, with built-in fluorescent lighting, is shown on p. 39. Other a.c. auxiliary installations have been completed for the San Fortunato, San Flaviano, San Felipe and San Fabian of the Eagle Oil & Shipping Co. Ltd., and the Hygromia of Shell Tankers Ltd., all of 18,000 tons.

Another new Canadian Pacific liner, the Empress of England, was launched in May, and is being equipped with Osram cold cathode lighting in all public rooms on a scale similar to the installation in the Empress of Britain, which went into service last year. Some two miles of ivory and gold tubing will be installed. A wide variety of decorative tungsten lighting fittings is being supplied for the same ship. The international reputation which the Company has established in marine cold cathode lighting is well exemplified by the fact that Osram tubes are being installed in the public rooms of the Gripsholm, now under construction for the Swedish-America line by Ansaldo at Genoa.

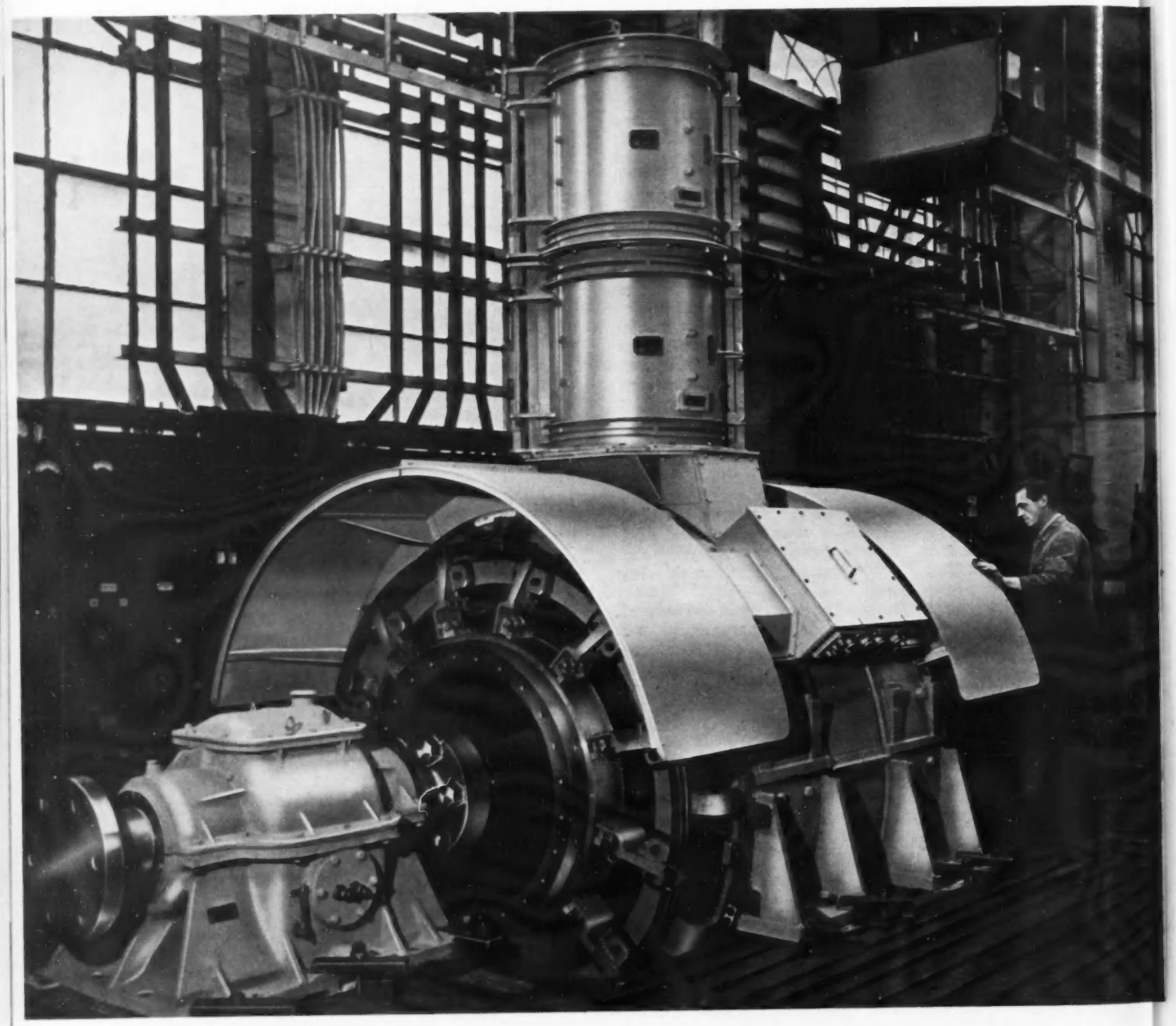
AIRCRAFT EQUIPMENT.

Some 35 airlines in all parts of the world use G.E.C. aircraft equipment. New items are continuously in course of development to meet a demand as varied as it is extensive. A recent example is the production of a coffee-making machine to meet the growing requirement for serving passengers with coffee freshly-made in flight instead of carrying supplies from ground kitchens in heated containers. This experimental unit will make one gallon of coffee from cold in 29½ minutes and a second gallon immediately after in 23½ minutes. The unit consists of a Monel metal boiler feeding into the bottom of a Pyrex glass container. The coffee is placed in a basket in the base of the container and boiling water is passed up through the coffee and down again on draw-off. The coffee maker is fitted with a separate steam outlet which will enable the operator to heat milk or other liquids as well.

It is now increasingly common to provide individual lighting for passengers so that they can continue to read or write without disturbing others when the general cabin illumination is off. A new unit, the Vickers spotlight, developed for installation in the Viscount 802, provides this facility when seats are arranged two or three abreast. The lights, in banks of two or three, are in ball and socket mountings so that each can be trained to project a 17 in. circle of light on one seat in the row and then locked in position. They are mounted in a backplate which fits into the passenger call panel and are individually switched. The Viscount 802 uses twelve three-way and seventeen two-way sets of the spotlights, which will also be installed in all future versions of this airliner. Single-light units of the same design are being supplied to the Scandinavian Airlines System.

New types of aircraft coming into service on the inter-Continental routes will also carry the Company's equipment. Air-circulation ovens, heated beverage containers and other G.E.C. items now standard in B.O.A.C. aircraft will be supplied for the Boeing 707 four-jet airliners ordered for the Corporation's trans-Atlantic services, and for the Douglas D.C.7C aircraft.

Motive Power and Services for Transport

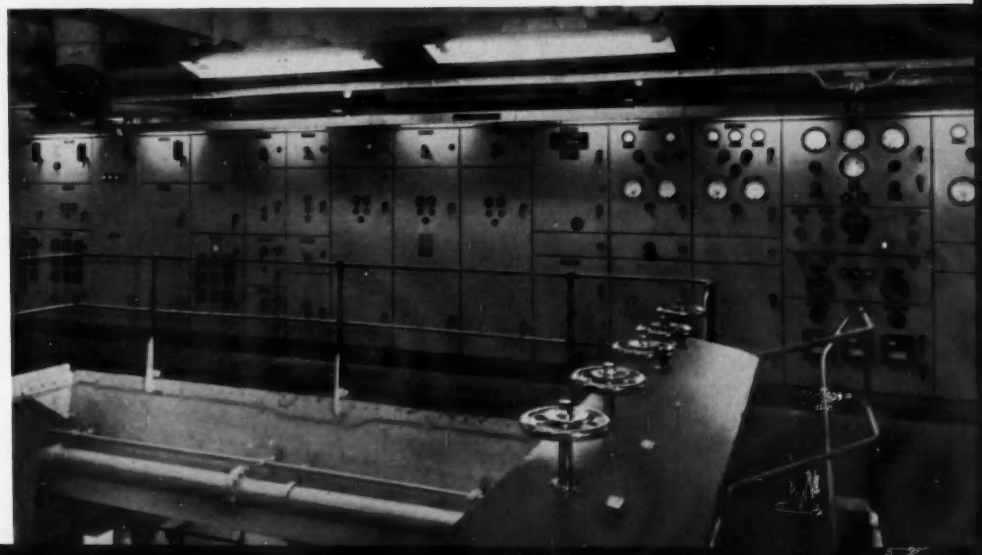


Left: The 1,350 h.p. double-armature propulsion motor for the R.R.S. "John Biscoe". Note the two-stage Aerofoil fan for motor ventilation mounted in trunking on top of magnet frame.

Top right: The MV "Bergensfjord" of the Norwegian-America Line, which made her maiden voyage in 1956, was the first British-built passenger ship to have all a.c. auxiliary services.

Centre right: Equipment was completed during the year for 32 four-car 1,500 volt d.c. train sets for the new Liverpool Street-Southend (Victoria) electric service of British Railways, Eastern Region.

Right below: The main switchboard of the tanker "Samuel Ugelstad" is representative of many supplied for the growing number of ships of this type which are using a.c. auxiliary power.



Lamps and Lighting

LAMPS.

As most types of electric lamps become increasingly complex, their production calls for greater technical skill. The requirements to be met by the final product are continually being made more stringent, as is witnessed by the fact that both fluorescent and tungsten lamps have recently been the subjects of new British Standard Specifications. The introduction of a complete colour specification for fluorescent lamps makes this particular Standard the first ever to define colour and colour-rendering properties.

MERCURY, FLUORESCENT AND SODIUM LAMPS.

An intensive programme has been carried out at the Osram Lamp Works to increase production facilities, reduce costs and make continuous improvements in the design and performance of high-pressure mercury lamps with phosphor-coated jackets. The small size, high luminous efficiency and pleasing colour-rendering properties are all popular features of this light source. Two recent additions to the range of these mercury fluorescent lamps are the 1 kW and 250 W ratings. The former is a colour-corrected version of the well-known 1 kW High Bay mercury lamp designed for low-cost high-intensity industrial lighting.

The high efficiency of the HPMV lamp is due to the fact that the most powerful spectral lines occur near the peak of the visibility curve. Any attempt to improve the colour-rendering properties by merely modifying the emission spectrum would therefore give rise to some loss of luminous efficiency. An alternative approach is to use a phosphor that will convert the ultra-violet radiation in the discharge into additional visible spectral bands.

One difficulty arising in the choice of phosphors for use in HPMV lamps is the high temperatures at which they have to operate. It is therefore of importance that several phosphors have now been found which continue to emit strongly at temperatures above 250 deg. C. It is by using these new materials that the colour-rendering of Osram HPMV lamps has been improved without appreciably lowering efficiency and, indeed, sometimes even with an improvement in this respect.

High-efficiency colour-corrected mercury fluorescent lamps are now available in ratings from 80 W to 1 kW. The 250 and 400 W ratings are being used for street and area lighting installations where a high level of illumination with good colour-rendering properties is required. The 80 and 125 W sizes are finding application in side-street lighting and in smaller outdoor installations such as railway platform lighting. Using the 125 W lamp together with 200 W tungsten lamps has enabled a new shop window lighting system to be developed. In comparison with other systems of the same overall wattage, this gives better colour-rendering properties at almost twice the intensity of illumination.

The performance of the older types of 250 W and 400 W HPMV lamps used for street lighting has been improved. The average light output throughout life has been increased from 7,750 to 8,750 lumens for the 250 W lamp, and from 13,600 to 15,600 lumens for the 400 W lamp.

The efficiencies of Osram fluorescent tubes in most colours, lengths and ratings have been increased, in some cases by up to 12 per cent. This is shown in Table 1, where the old and new figures for the average light output during the first 5,000 hours of life are given for a selection of Osram tubes.

TABLE 1.

Efficiencies of Representative Osram Tubes.

Colour	Length	Rating	Former Efficiency	Improved Efficiency
Daylight	5ft.	80 W	49 lm/W	51 lm/W
Warm White	5ft.	80 W	52 ,,	53 ,,
Daylight	4ft.	40 W	51 ,,	55 ,,
Warm White	4ft.	40 W	54 ,,	57 ,,
Daylight	3ft.	30 W	47 ,,	49 ,,
Daylight	2ft.	40 W	31 ,,	33 ,,
Daylight	2ft.	20 W	38 ,,	40 ,,
Daylight	1½ft.	15 W	33 ,,	37 ,,

In the continuous effort to improve the performance of fluorescent tubes, a knowledge of the factors influencing the production of short-wave u.v. radiation in the low-pressure mercury discharge is of great importance. In particular, methods of maintaining the production of this type of radiation, even under conditions of high lamp loading, are being studied.

New additions to the range of fluorescent tubes are the 4 ft. and 5 ft. reflector tubes, which are interchangeable with existing tubes of the same length. A layer of titanium dioxide, covering approximately two-thirds of the circumference, provides an internal reflector which directs most of the light from the fluorescent powder downwards through the remaining third, the reflector layer itself absorbing only 10 per cent. of the total light output. A comparison of the

light distribution curves for the reflector and conventional tubes (fig. 1) shows that the former provides almost twice as much light on the working plane as a conventional tube operated in a fitting without directional characteristics. A further important advantage is that the level of illumination is maintained despite the presence of dust on the upper surface of the tube. Dark or dirty ceilings thus have less effect on the overall illumination. Where bare tubes are used in shop window installations, the new tube directs more light on to the display instead of into the street. It also shows to advantage for indirect lighting and in positions where lack of space prevents the use of a reflector fitting.

Fluorescent tubes, with spectral characteristics specially suited to photo-printing and photographic reproduction techniques, and which provide the shortest printing times yet achieved, have now become available. In the " black light " series, the phosphor used emits primarily long wave u.v. radiation. Tubes with phosphors emitting a blue light are also available.

Developments in light sources which employ fluorescent materials are naturally closely linked with improvements in the phosphors themselves. An acceptable coating appearance with halophosphate phosphors could hitherto be achieved only by reducing the size of the relatively coarse particles present in the powder. The milling technique used for this led to a loss of brightness in the finished coating. Recent developments have enabled halophosphate powders to be prepared with grain sizes small enough for application to lamps without further milling. This technique has already been used for making experimental tubes and has been shown to reduce materially the loss in phosphor efficiency which previously occurred during the lamp-making process.

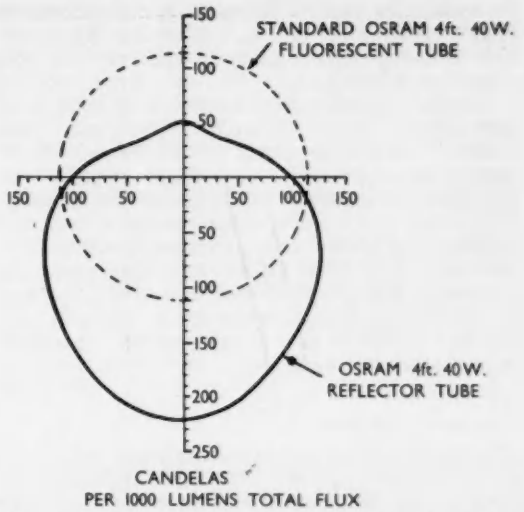


Fig. 1.—Comparison of light distribution of 4 ft. 40 W reflector tube and standard fluorescent tube.

The quantum efficiency (a measure of the ability to transform incident radiation into emitted light) of certain halophosphates is as high as 90 per cent. While that of most long u.v. excited phosphors is about 50 per cent., a notable exception is provided by the newly-developed group of phosphors used in

Fig. 2.—Street-lighting with Osram integral sodium lamps at St. Pancras.

the colour-corrected HPMV lamps mentioned earlier. These barium strontium lithium silicate phosphors have a much higher quantum efficiency for this particular radiation.

The new integral sodium lamp, in which the inner bulb is hermetically sealed within a glass outer jacket, is now in production in the 45, 60, 85 and 140 W ratings. Among the advantages of the integral design are improved reliability ; its convenience for handling, transporting and stocking ; the existence of only one surface on which dust can accumulate ; and the fact that the jacket protects the arc tube from atmospheric conditions, giving reliable starting in all weathers. The importance of these advantages is reflected in the growing popularity of this light source for street-lighting applications (fig. 2).

Incandescent Lamps.

The substantial total gain in the efficiency of G.L.S. lamps during the past five years is shown in Table 2, where the figures given indicate percentage improvements (1950-1=100 per cent.).

TABLE 2.

Quality Improvements of Osram Single and Coiled-Coil G.L.S. Lamps.

Year	1950–1	1951–2	1952–3	1953–4	1954–5	1955–6
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
40 W	100	100·25	101·5	103	105	107
60 W	100	100	101·5	103	104	105
100 W	100	98·5	100	100·5	101	102

Standards of lighting in the home continue to improve. The 100 W lamp is now steadily replacing the 60 W rating which was previously the most popular. The continuous effort being made to lower the manufacturing costs of lamps of 100 W and below is leading to a reduction in the bulb sizes of lamps in these ratings. A reduction in the bulb size of the 200 W lamp to 80 mm. dia. has also been achieved without any sacrifice in quality.

The introduction of these smaller bulbs has required the solution of a number of technical difficulties, the most important being the effect of the increased bulb temperature on the capping cement. New cements now in use will withstand a temperature 40 deg. C. higher than previously throughout the full life of the lamp. In addition, their end-of-life torque strength greatly exceeds the maximum required by B.S. 161/1956.

A new range of gas-filled tungsten lamps, Pink Pearl, has been produced to meet the demand for a "softer" light for domestic use. These lamps, available in the 60, 100 and 150 W ratings, are tinted a pale pink so that they will produce a warm, diffused light without glare. The maximum light output at the desired colour-rendering has been obtained as a result of considerable research into methods of producing the tinted filter. The alternative manufacturing techniques involve either the application of a coloured frit to the outside of the bulb or the use of a diffusing coating of pink pigmented titanium oxide on the inside.

A further interesting development in the construction of G.L.S. lamps is a tendency to use a hardened aluminium alloy in place of brass for bayonet-type lamp caps. The appearance of the finished lamps can be enhanced by this means.

The growing demand for small tungsten lamps is being met by the introduction of several new types, including high-voltage 10 W lamps, and those intended for decoration and similar purposes. Sub-miniature lamps are increasingly required for instrument lighting, often in vehicles and aircraft, so that the lamps now available for use in these applications have been specially designed to withstand vibration and shock. Miniature tungsten lamps, in which the usual cap has been replaced by a push-in pin mounting, are now under development, for use wherever the capping cement would suffer from high ambient temperatures. The use of the push-in pin also simplifies mounting on panels.

A revised design of the 10 kW lamp for film studio spotlights embodies the internal bipost construction and an internal cap with solid pins. This makes the lamp far more robust and thus increases its popularity with lighting maintenance crews. Lamps with the new cap are fully interchangeable with earlier types.

For the lamps incorporated in cinema projectors, the use of coiled-coil filaments with a special mounting, designed to improve the uniformity of screen illumination, has been extended to include the new high-voltage 250 W rating.

LIGHTING.

Fluorescent Lighting in the Home.

Tubular fluorescent lamps were first introduced in 1939, and a range of sizes suitable for domestic lighting became available after the war. Until quite recently, however, their application was confined to kitchens and bathrooms, using simple fittings. As tubes of improved efficiency and colour have become available, they have been increasingly used in other parts of the home, either for background lighting in conjunction with the traditional standard and table lamps or in the new attractive fittings specially designed for use in the home.

Control Gear.

A simplified method of operating the new integral sodium lamp entails running the lamp from a 415 V a.c. supply by connecting it between phases of the normal 240 volt mains. A simple series choke may be used as ballast instead of the usual step-up auto-transformer, thus achieving a substantial saving in gear costs. Although the potential available for starting the lamp is some 55 volts lower than that from the transformer, reliable starting is obtained

because the arc tube is protected by the jacket from the effects of high humidity, which is known to increase the starting voltage of low-pressure discharges. The preferred arrangement of this circuit uses two similar chokes, one in each supply lead, to suppress the injection into the mains of high-frequency oscillations generated by the lamp, which might cause radio interference.

Further improvements have been made to the new starterless "C" type gear for fluorescent lamps, which provides reliable starting under a wide range of ambient conditions and avoids the maintenance problems of circuits employing starter switches. Although the start is a little slower than that of the earlier instant-start gear, it is smooth and provides a substantial glow in the tube almost immediately on switching on.

Several dimming equipments (of the general type known as "E-control") have recently been developed. While the basic thyratron unit has been standardised, the versatility of these equipments has enabled the particular control requirements of each installation to be met. In some cases, the load has been divided between as many as four thyratron units. In one instance—the lighting of lecture rooms in which only two levels of illumination are required—a single "E-control" equipment is used to control a fluorescent lighting load considerably in excess of its normal capacity. The high level is provided by connecting the tubes directly to the supply, while the lower brightness is obtained by feeding them through the dimmer, pre-set at the required level. Measures have also been devised to ensure that sound amplifying or recording equipment will not pick up background noise from the dimming equipment.

In another case, where a rapid dim is required, the normal motor-driven potentiometer was adapted to bring eddy current braking into play at each end of its travel. This absorbs the inertia of the moving parts quickly enough to avoid overrun.

FITTINGS.

A new range of lighting fittings has been developed for use in acoustic tile ceilings, with special emphasis on maintenance and general appearance. The fittings accommodate 2, 3 and 4 fluorescent tubes and replace 1, 2 and 3 tiles, each measuring 2 ft. × 2 ft. (fig. 3). A simple fixing device enables the fitting to be supported from the framework which carries the tiles, thus reducing installation costs to a minimum and at the same time providing a flexible lighting system in which complete fittings may easily be removed when desired. The underside may be a diffusing "Perspex" panel or an "egg box" louvre, carried in a frame which can open from either side, an advantage where access space is restricted.

New fittings for teaching accommodation in schools have been designed specially to meet the requirements of the Ministry of Education's Statutory Instrument No. 473, 1954, Clause No. 51. A wide selection of fittings is thus available for all locations in schools, including classrooms, assembly halls, corridors, gymnasia, etc.

Fig. 3.—Fittings in an acoustic tile ceiling at the Cheltenham laboratory of the National Coal Board.

A specially designed fused mains terminal block is being incorporated as standard in fluorescent fittings, so that each fitting now embodies its own protection and no longer has to rely on circuit fuses, which have such widely varying characteristics. The fuse incorporated in the terminal block is a specially reliable form of the standard miniature cartridge type of 2 A rating. Since these fuses are located at the input to the whole of the fitting, they serve as protection against any fault arising in the tube, chokes, capacitors or internal wiring. The fuse is carried in a polythene moulding, which is designed for easy withdrawal and also provides protection against accidental contact with parts which may be "live".

MATERIALS.

The increasing use of a translucent plastic in lighting techniques has been most marked where neon signs are concerned. Its advantages are due to its properties as a diffuser of light. Hitherto signs which were most effective at night have been marred in daylight by the appearance of the exposed light source.

Using the plastic to its full advantage, the sign-maker can reproduce the true face-value of the letter form while maintaining the brilliance of illumination. At Claude-General Neon Lights, Limited, a new department, with a specially planned and equipped workshop for the fabrication and forming of plastic signs, has now been opened. Much of the shaping is done with high-speed routing machines. The circular and jig saws have special tooth spacing suited to the material, and all drills are " backed-off " to avoid cracking the " Perspex " sheet used. A controlled infra-red oven can reduce the sheet to a pliable softness to achieve the desired contours. Expert pattern makers supply the many individual moulds and formers required, which are retained in store for possible future use. A drying room has been installed to take advantage of the latest and quickest methods of cementing the joints.

Advantage is also taken of the merits of plastics for fluorescent lighting fittings. The new range of decorative commercial fittings includes several additions which use a special corrugated form of this material.

STREET LIGHTING.

The increasing part being played by architects in the design and choice of street-lighting lanterns has led to the production of a wider range of these products. Since capital cost is also assuming a greater importance, a range of smaller, neater and simpler lanterns must be available for the purely functional, non-decorative lighting of main and side roads.

About 20 new lanterns have been designed, the opportunity being taken to incorporate improvements which make the new lanterns even better for their purpose than the previous models. The improvements take into account the results of research, new manufacturing techniques and new finishes, as well as compliance with changing fashions.

For sodium lighting, not only have eight new lanterns been designed but a new transformer has been developed. This has improved proportions, so that the lanterns can be slightly smaller without any loss of electrical efficiency.

There are four new vertical (post-top) fluorescent lanterns to accommodate from two 4 ft. 40 W tubes to four 5 ft. 80 W tubes. The special " Blackpool " lantern, a vertical decorative unit consisting of a tapered " Perspex " cylinder housing four, six or eight 2 ft. 40 W fluorescent tubes, has given good service. Other new fluorescent lanterns include a design for main road lighting which can be used for two, three or four 5 ft. 80 W tubes mounted horizontally. There are also wall-mounting lanterns to carry two 5 ft. 80 W tubes and two 4 ft. 40 W tubes. For side-street lighting a lantern has been developed to carry two 2 ft. 40 W tubes. All of these incorporate an improved optical system giving the lanterns a narrower and neater cross-section. The appearance has been improved by concealing the bracket in the top.

A new post-top lantern has been designed for 60 to 200 W tungsten lamps or 85 and 125 W mercury lamps for side-street lighting, while a small lantern with a " Plastifractor " injection-moulded " Diakon " bowl has been introduced for the same purpose. The latter also takes an alternative glass bowl.

An entirely new type of optikon has been used in a main-road lantern for 250 or 400 W HPMV lamps. The advantages of placing the light source at a large angle to the refracting surfaces on the enclosing bowl are being exploited to the full for the first time. The resulting lantern is simple and robust, with a minimum of separate parts. An interesting and modern appearance with particularly clean lines is achieved by keeping the lamp horizontal and inclining the bowl. The primary optical system is a large refracting bowl using curved-faced prisms ; its simplicity avoids the loss of flux resulting from complicated optikons.

A lantern has been designed with a refractor bowl which has a light distribution ideally suited for lighting tree-lined side streets. The same optical system may also be more satisfactory than existing designs for side streets without trees, so that a standard optical system for all side-street lanterns has been achieved.

RAILWAY PLATFORM LIGHTING.

A new lantern has been designed to meet the requirements of the British Transport Commission for lighting railway platforms, particularly those parts of passenger platforms which are not covered by a roof. An aluminium canopy and opal plastic bowl completely enclose two 120 mA special grid-type cold cathode fluorescent tubes (total length about

Fig. 4.—New bi-directional runway light giving high-intensity light distribution combined with some omni-directional orbiting light.

Fig. 5.—1 kW floodlight for London Airport.

30 ft.) and their controlling transformers. The two safety devices incorporated are a relay cut-out, which breaks the mains supply circuit if there is a leakage of high-tension current, and a switch which automatically opens when the lantern is opened. Cold cathode lighting was chosen because of its long life and consequent saving of maintenance time. The light output is about the same as that from a 500 W tungsten lamp, and is achieved with a consumption of 243 W. The lantern displays the station name by day and night, and is dust proof, requiring the minimum amount of cleaning.

AERODROME LIGHTING.

Among the more important additions to the range of aerodrome lighting units are new runway and taxiway lights featuring prismatic glass optikons. The ZA/105 runway light (fig. 4) uses a particularly interesting heat-resisting glass refractor, designed to give a bi-directional high intensity light distribution combined with a certain amount of omni-directional orbiting light. Intended for mounting adjacent to the runway or taxiway, it is provided with a two-pole moulded Neoprene plug and socket disconnecting device in the mounting system.

A 1 kW floodlight, developed to an Air Ministry specification for illuminating the central terminal apron area at London Airport, also incorporates a pressed heat-resisting front glass (fig. 5). This pressing is designed to control the light distribution in both the vertical and horizontal planes, and is used in conjunction with a highly-polished aluminium reflector which forms the body of the floodlight. The B2 lamp is mounted axially with its cap at the front of the unit, the holder being on a three-way spider just inside the glass. The rear of the reflector is hinged for easy maintenance and relamping when the floodlights are mounted round a small platform at the top of a tower.

The use of an angle-of-approach indicator in bad visibility or daylight conditions is possible for the first time with the introduction of a new high-intensity indicator (fig. 6). Comprising the customary " lantern slide " projector which shows flashing signals coloured in bands to indicate the approach angle, this unit is considerably larger and incorporates a 2 kW lamp. At full brilliancy the coloured beams have an intensity of more than 20,000 candelas, nearly 100 times the figure for earlier types.

Also new is a self-contained aerodrome identification beacon, rated at approximately 1 kW. A number of cold cathode fluorescent green tubes is mounted in the form of a cylinder in a glazed housing, on a cast-iron rectangular base containing all the auxiliary electrical equipment and flashing mechanism to give the appropriate two-letter code signal.

PRODUCTION.

GLASS INSTRUMENTATION.

As more new functions are found for glass, it must be produced in ever more complicated shapes and to increasingly precise tolerances. To obtain these properties in the finished components with the high production efficiencies obtainable on automatic glass-forming machinery, such as bulb-blowing

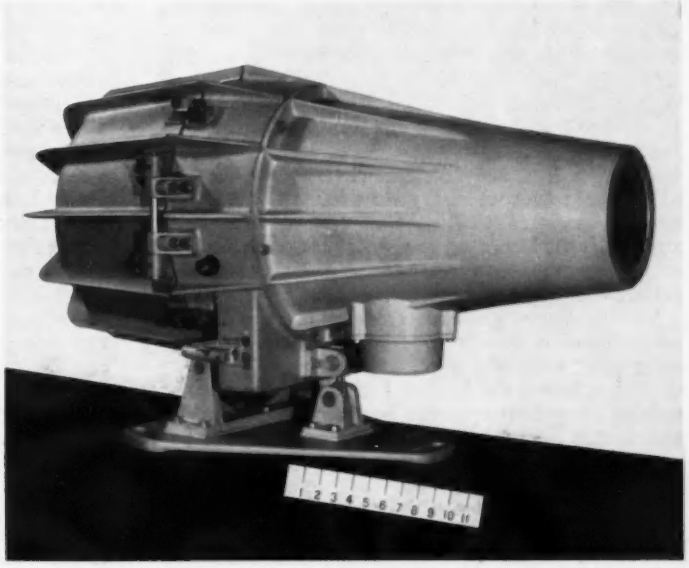


Fig. 6.—High-intensity angle-of-approach indicator for airfields.

machines, special controls are required on the glass melting furnaces. For example, the rate of glass flow from the furnaces to the machines must be controlled to within fine limits, in order that the precise weight of glass required for each cycle of the machine operation is delivered. This can be achieved only if there is correspondingly close control of the temperature and the level of the molten glass in the tank, since the latter determines the hydrostatic head forcing the glass through the exit orifice. Provision of accurate instruments for this purpose has become a feature of modern glass-melting equipment.

In a tank melting glass for machine-blown bulbs, the level is ascertained by dipping a platinum electrode which has a vertical reciprocating motion and completes an electrical circuit when it touches the surface of the molten glass. Information on the exact level of the glass is then conveyed to the controlling instrument, and corrections are effected by adjusting the delivery of raw materials to the furnace. While the glass travels along a shallow channel from the tank, its temperature is reduced from the melting point to that required by the machine. Two pyrometers installed at different points on this channel measure the temperature of the glass at or near its surface. Through their respective controllers, they then alter the flow of gas used to heat the separate sections of the channel. These are typical examples of the instruments which enable the level of glass in the tank to be maintained constant within $\pm$ 0·01 in., and temperatures in the region of 1,100 deg. C. to be controlled within $\pm$ 1 deg.

A development which should assist, incidentally, in temperature control is the application of electric heating to glass melting, with its advantages of using heat more efficiently and reducing the size and cost of the furnace. At present the use of power is largely confined to electric boosting, that is, the insertion of electrodes into the molten glass and generation of heat within the mass of glass itself in addition to the heat normally obtained by combustion of oil or gas. Full-scale trials of this technique have recently been carried out on neutral glass, soda glass, and on a soda-glass tank for the production of tubing. Electric boosting using molybdenum electrodes does not affect the colour of the glass produced, and may give an increased yield of glass from a given tank size, a slightly improved quality for the same melting rate, or an increased furnace life as a result of a lower surface temperature of the molten glass.

The quality of glass required for lamp and valve manufacture is greatly superior to that needed for most other industrial applications. When the standards are lower, the increased yields due to electric melting are quickly apparent, but research has already shown that electric melting with molybdenum electrodes may prove advantageous for this application also.

Special instrumentation has recently been introduced into the fabrication of glass tubing for fluorescent tubes. It has been known for some time that variation in the gas-filling pressure affects the luminous efficiency of the tubes. Since the filling method consists of "bleeding" in the gas at a set pressure for a fixed time, the main cause of such pressure variation was the use of too wide a range of glass tubing. Tolerance on the outside diameter of the 37 mm. tubing used was $\pm$ 1 mm., and it was uneconomic to reduce this in manufacture. By sorting the tubing into grades of closer tolerance, however, the gas-filling controls could be adjusted to maintain the correct objective gas pressure. Fully automatic gauging is now carried out in two stages. The outside diameter of the tubing is continuously measured and recorded before cutting. Tubing outside the tolerance limits is automatically rejected, warning of the need for adjustment of the tube-drawing machinery being given at the same time. After cutting, the second gauging unit sorts the tubes into sub-grades in the upper and lower halves of the tolerance range.

Decreasing the gas pressure increases luminous efficiency but reduces the life of the lamps. While the average life was satisfactory before sub-grading of the tubing was introduced, the spread of gas pressure prevented a reduction of pressure to increase efficiency. Sub-grading has now made it possible to halve the spread, so that the gas pressure can be reduced to increase the efficiency without increasing the number of early lamp failures.

Internally-Enamelled Tubing.

Architectural lamps are now being made from internally-enamelled machine-drawn soda glass tubing. This material, which was developed by the Company, produces lamps of more uniform dimensions and opacity than did the former hand-drawn solid-opal tubing. It has also distinct economic advantages over the system by which short lengths of lead glass tubing are enamelled for the same purpose. Strict control of the technique in all stages is needed to obtain the required uniformity of opacity, and it is necessary for the thermal expansion of the enamel to be matched to that of the glass so that the minimum amount of strain exists between enamel and glass, and tubes of adequate mechanical strength can be produced.

By melting the base glass for the enamel in a small tilting furnace and pouring it into water, it is brought into a suitable condition for ball-milling, when the opacifiers are added. The finished enamel or slip is a suspension of these materials in industrial alcohol, and two important factors to control in the process are the particle size of the slip and the thickness of coating inside the tubing. The enamel is applied by the welling-up process, the required thickness being obtained by controlling the rate at which the slip drains away. Standard five-foot lengths of soda-glass tubing machine drawn by the Danner process are employed, and, after enamelling, drying and firing, each length is carefully inspected and cut to give the minimum wastage. The cut lengths of enamelled glass thus obtained are suitable for the

manufacture of architectural lamps ranging in length from 6 in. to 4 ft.

Improvements in the enamel have enabled the required thickness of the coating for the specific degree of opacity to be reduced to the minimum. Besides economising on expensive enamel, the thinner coat is less liable to the formation of bubbles and other defects. The reduction of coating thickness greatly facilitates lamp-making, and increases the mechanical strength of the finished tube. Lamp tubes are curved after enamelling and firing without in any way interfering with the uniformity of the coating.

OPAL GLASS.

Hand-blown bulbs of special opal glass have been used for many years in the manufacture of decorative and similar types of lamps. It was known from X-ray diffraction evidence that the opacification of the glass, which must be sufficient to obscure the glowing filament completely in the finished lamp, was produced by the precipitated particles of sodium and calcium fluorides.

While rejections of the finished bulbs were due to a variety of glass faults, most of them were failures to obscure the glowing filament. Therefore, it seemed likely that, of all the processes concerned in the production of the glass, the actual opacification method might well be the least reliable. The size and distribution of the precipitated particles were considered as possible causes for this type of reject; the viscosity, and therefore the alumina content of the glass, affecting their rate of growth, and the fluorine content determining their number per unit volume. Opal glass compositions are notoriously corrosive on aluminous slip-cast refractory materials, so that large variations in the alumina content might be expected. In addition, a large proportion of the fluorine from the batch was volatilised during the melting process, again giving rise to variations in composition.

Daily chemical analyses carried out on samples obtained from the tank in which the glass was produced confirmed that these two factors did in fact give rise to considerable variations in the chemical composition of the glass. Results were plotted against glass efficiency, and, from the three-dimensional diagram shown in fig. 7, it was possible to determine

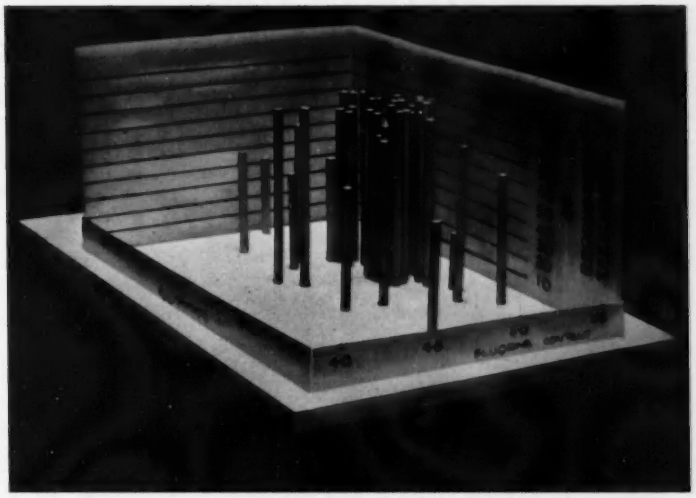


Fig. 7.—Three-dimensional diagram of fluorine and alumina in opal glass, plotted against glass efficiency.

critical values of alumina and fluorine which gave the best and most consistent results. The founding technique was then modified to ensure that these values were obtained in production. The presence in the diagram of one or two "strangers", which do not agree with the general family of results, shows that additional variables do exist and it is believed that these are associated with the operation of the furnace itself.

Some Lighting Installations of the Year

Fluorescent lighting simulates clear daylight conditions at the Warwickshire County Cricket Club's new indoor cricket school at Edgbaston, Birmingham, enabling training to proceed during the winter.

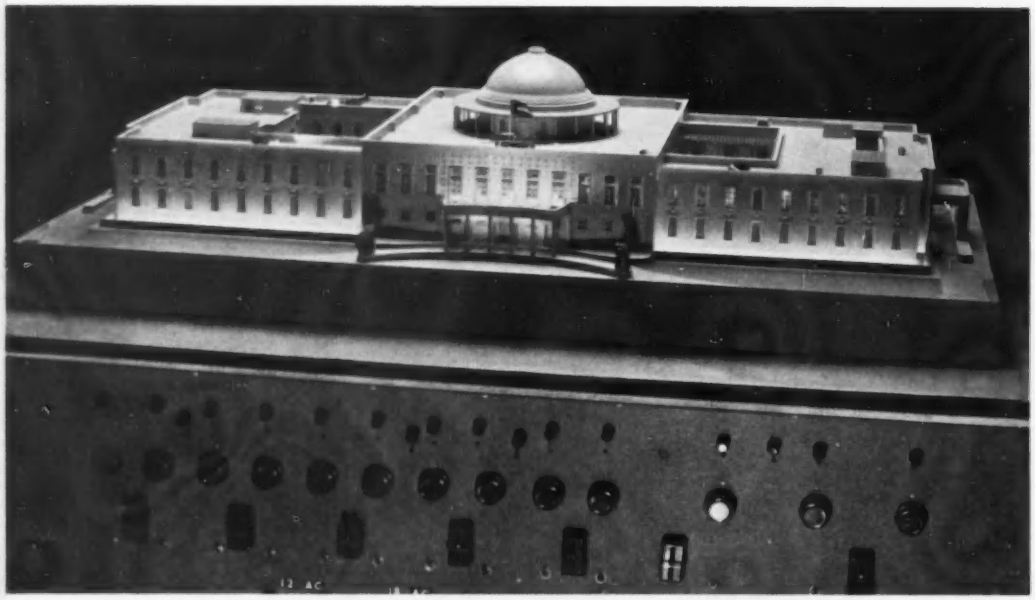
New entrance foyer to an extension of the Connaught Rooms, London, showing some of the candelabra and bracket fittings supplied for the foyer, new banqueting rooms and luncheon restaurant.

Lighting trunking with Osram fluorescent tubes over the assembly lines at the new Solihull workshops of the Rover Car Co. Ltd., where some 2,000 yards of trunking have been installed.

Lighting trunking attached by conduit to a false ceiling, installed for freedom from dust and to help temperature regulation, in the Stork Margarine plant of Van den Berghs & Jurgens Ltd. at Purfleet, Essex.

Osram cold cathode lighting in the Empress Room of the new Canadian Pacific liner, "Empress of Britain", in which some two miles of the tubing are installed.

Some Lighting Installations of the Year



Above: A model used to study the effect of different flood-lighting schemes.

Left: A Claudgen sign and white outlining make an impressive picture of the corner site occupied by C. & A. Modes Ltd. at Kingston-on-Thames.

Above: Glare-free cold cathode lighting integrated with the auditorium design at the Cecil Cinema, Hull. Recessed fittings near the proscenium give a night sky effect.

Left: Lighting incorporated with a suspended acoustic ceiling at the store of A. W. Gamage Ltd., Holborn.

Left: Artistic combination of lighting and décor at the House of Braganza restaurant, Frith Street, Soho.

The Year's Progress

Telecommunications

TELEPHONE EQUIPMENT.

Steady progress has been made in the development of electronic devices to improve the operation of existing electromechanical switching systems. The electronic keysender for switchboard operator service, which enables operators to set up calls very quickly compared with the use of the standard telephone dial, has given satisfactory service. Its freedom from the need for routine adjustment is proof that this type of equipment will have a very low fault rate.

The development by the G.E.C., as designated contractor in conjunction with the British Post Office, of two types of register-translator equipment has reached its final stages. These equipments allow direct dialling of trunk calls by subscribers, and models are now being put on field trial in preparation for the introduction of this service in Britain. Both types of register-translator perform the same functions: receiving dialled information, storing it, translating it to the form necessary to set up a route to the required exchange and subscriber, determining the fee rate for the call, and operating further equipment which ensures that the calling subscriber is charged appropriately. One type incorporates the latest developments in electromechanical switching practice, while the other employs the electronic techniques previously used in the construction of the electronic keysender. Both types are likely to be useful in a subscriber trunk network.

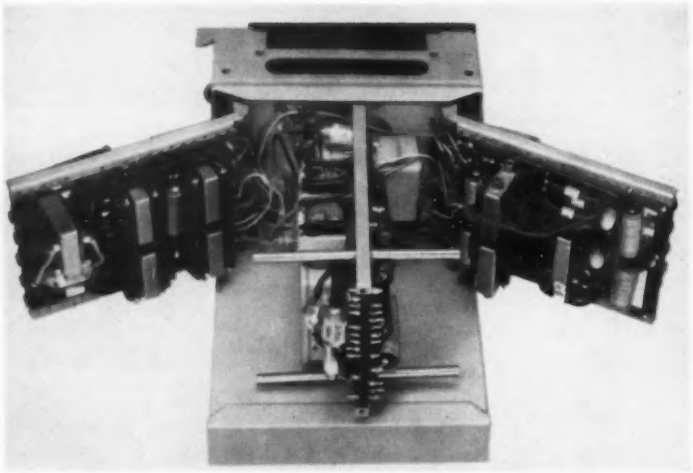


Fig. 1.—Hinged deck construction of multi-channel V.F. telegraph equipment.

ELECTRONIC SWITCHING.

The fundamental research and development work carried out jointly by the Telephone Works and the Research Laboratories has produced most encouraging results and a prototype all-electronic telephone exchange has been in operation at the Research Laboratories for eight months.

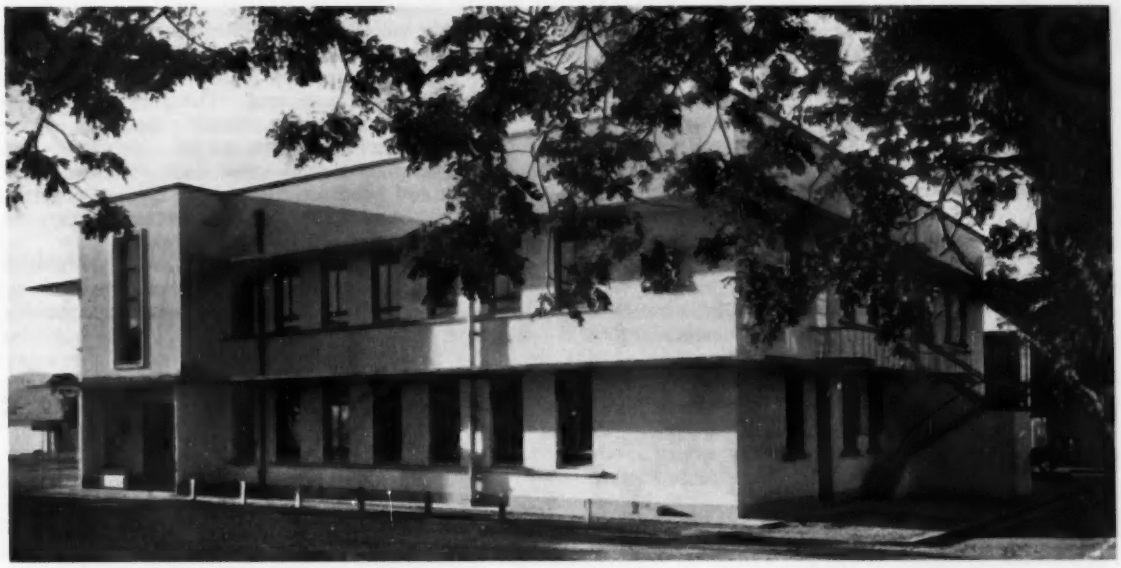
Similarly, the British Post Office and the British telephone industry as a whole have carried out research and development in the field of electronic switching to such an extent that it is felt that the way is now clear to produce a practical experimental electronic telephone exchange suitable for public service. The combined efforts of the Post Office and of the telephone industry are now being devoted to this task, the success of which depends entirely on the closest co-operation between the Post Office and industry. The G.E.C. is proud to be able to play an appropriate part in this joint effort which will undoubtedly have a most beneficial effect on the telephone service in the United Kingdom and in many countries throughout the world.

LINE COMMUNICATIONS.

The predominant trend in communication equipment design is towards increasing the degree of miniaturisation, with its associated advantages of reduced space, weight and cost. The development of the smaller equipment must of course be achieved without any sacrifice of the reliability of the smaller components used, while retaining the accessibility required for testing and maintenance on site, in spite of the closer spacing of those components. The former requirement is met by the development and use of such highly stable components as germanium diodes for power and frequency changer work, polystyrene foil condensers, miniature toroidal cores, transformers and stable resistors, and quartz crystals of special cuts. Accessibility is achieved by using the type of construction illustrated in fig. 1, in which decks of equipment open out on hinges to expose the components.

The increasing use of miniaturisation during the past ten years is clearly seen from fig. 2, which shows

OVERSEAS TELEPHONE EXCHANGES



The first automatic telephone exchange installed by the G.E.C. in Fiji, serving 2,600 subscribers, is housed in this building in Suva.

Above: Interior of Mosul exchange, the most recent of several installed in Iraq.

Left: Locally-trained staff carrying out final inspection at Suva.

a channel panel and its associated ringer unit as manufactured in 1946, 1951 and 1956. In the last version, both sections of the equipment have become one small unit.

The use of the transistor has greatly facilitated progress towards the design of such smaller equipment. The small size, low power demands and negligibly low heat dissipation of the device have enabled units to be packed closely together without the problems of heat dissipation associated with valve equipment. The mains and battery equipment required are also correspondingly smaller and cheaper. Even greater advantages are the long life of the transistor and its low operating voltages, which greatly improves the life and reliability of all the other components in the equipment. Maintenance is thus reduced to a minimum.

The introduction of transistors and new circuit techniques has enabled a new carrier equipment to be developed for use over open-wire lines in rural areas where mains power supplies are not normally available. Special care has been taken to keep the power consumption to a minimum for operation from a small battery supply. Operating in the frequency band 4·6 to 175·4 kc/s, the equipment is designed to provide a maximum of ten speech circuits, each 300 to 3,400 c/s in width, in addition to the physical circuit.

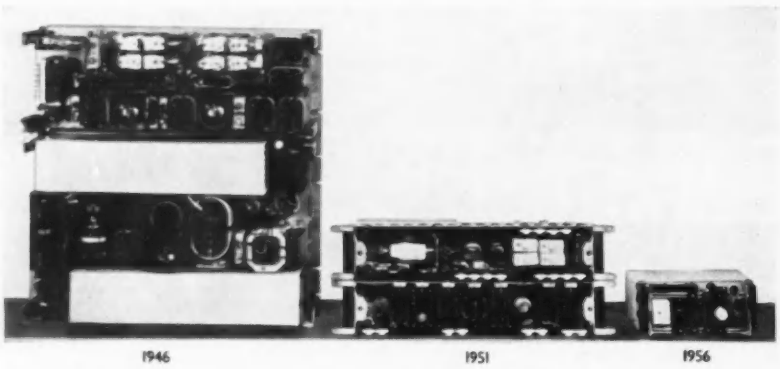


Fig. 2.—Progress in miniaturisation : channel panel and associated ringer unit in (L. to R.) 1946, 1951 and 1956.

The circuits can be stacked, enabling one or more to be terminated at different points along a route. This feature is particularly important in areas where the number of circuits over a route is to be increased without making extensive changes to the open-wire construction, especially with respect to its transpositions. Lines already in existence can be used without the considerable expenditure usually needed to re-transpose them for carrier working.

By using transmitted carrier and double sidebands for each channel, the design of channel bandpass filters can be simple. The carrier frequency is used for signalling, which simplifies the design of the signalling receiver. The use of a compandor on each channel simplifies and cheapens the channel equipment and enables the new system to be operated over routes where standard systems, such as open-wire 12-circuit, already exist. Automatic gain regulation is a feature of each channel. The design of the bay layout for the system is so flexible that only as few circuits as are required need be installed. The use of a common channel panel unit, with detachable oscillator and bandpass filter units, reduces the need for spares to a minimum and helps to make the system flexible for re-routing.

Another early application of transistors has been to multi-channel voice frequency telegraph equipment. In the new system, the hinged " deck " construction has produced a unit which is compact, yet has sacrificed nothing in accessibility. In addition an alternative channel equipment has been produced in which the receive relay has been replaced by its electronic counterpart, the transistor switch. The equipment requires only one control, the " bias-adjust ". The system itself is of the frequency shift type, using a very stable oscillator with a fixed shift in frequency. The limiter at the receiving end gives a wide range of automatic gain control, allowing large variations in the line equipment without affecting the performance of the unit.

The increased demand for fully automatic dialling between exchanges mentioned earlier has affected the design of the carrier equipment which forms the basis of these networks. In the latest system, a signalling receiver, in which the signalling tone lies just outside the top frequency of speech, is built in as part of the channel panel. The actual signalling frequency is 3,825 c/s. The practical advantages of this " out-of-band " signalling system are immunity from voice operation of the signalling path and simplification of the trunk relay sets. The new channel panel is based on a single modulation stage with quartz crystal filters selecting the wanted sidebands in the range 60-108 kc/s. A reduction of 4 to 1 in size has been achieved in comparison with the 1951 equipment, and 16 to 1 compared with earlier equipment.

To convert a television video signal into a form suitable for transmission over a long-distance coaxial cable circuit, translating equipment must be used to shift the frequencies comprising the signal to a higher band. The Company is installing a number of such equipments for the British Post Office and these use a carrier wave at a power level which is high in relation to that of the sidebands conveying the useful picture information. The output distortion created

by this high-level carrier has led to severe difficulties in the design of a suitable line amplifier.

A new design of television translating equipment, in which the ratio of carrier to picture sideband power level is reduced, is nearing completion. This apparatus will handle picture signals for both 405- and 625-line systems ; the requirements of colour television are also being borne in mind. An improved 6 Mc/s line amplifier which will be capable of operating in conjunction with the new translating equipment is also under development.

COMPONENTS.

The increasing use of microwave frequencies for communication systems has led to problems concerned

Fig. 3.—Automatic equipment which monitors crystal frequencies.

with the choice or development of components suitable for operation in this frequency range.

Among the many new devices becoming available to designers are those which make use of the special properties of ferrites at microwave frequencies. By associating the ferrite with an attenuator in a length of waveguide transmission line, this can be made to have negligible loss in one direction while presenting a path with high loss to waves travelling in the reverse direction. Typical figures at 6,500 Mc/s are 0·3 dB forward loss and 20 dB reverse loss. These " isolators " can thus be used to remove unwanted reflections in feeders and between amplifier stages, and to decouple modulators from frequency-dependent loads. In another application of ferrites, the electrical length of a transmission line is made dependent on the direction of transmission. A " circulator " using this property will then separate " go " and " return " circuits in a common-aerial system.

Quartz oscillator crystals are now required to operate over wide temperature ranges with a very restricted frequency tolerance. A typical present-day requirement is that crystal frequencies should be within $\pm 0{\cdot}005$ per cent. over the range -55 deg. to $+90$ deg. C., and future demands are likely to be considerably more stringent. Among the many problems encountered in this development is that of the precise adjustment of the working frequency at ambient temperature. For many years, high-frequency crystals have been adjusted to frequency by loading the surface of the crystal element with a stable conducting electrode material, such as gold, using a sputtering or evaporation technique to deposit the metal film.

A completely automatic equipment, shown in fig. 3, has now been designed which monitors the frequency of the crystal while the metal film is being deposited by vacuum evaporation. By comparison with a sub-standard frequency, the evaporation cycle is automatically stopped when the crystal reaches the desired frequency. In the present equipment a crystal can be adjusted to within $\pm 0{\cdot}0005$ per cent. in less than two minutes. This accuracy of adjustment entails effectively controlling the mean thickness of the gold film to within one atomic spacing.

HIGH-FREQUENCY FILTER CRYSTALS.

A new development in the design of filters has arisen from the use of quartz filter crystals at much higher frequencies than previously. For example, in the design of crystals for use at 4,340 kc/s in pilot-stop filters for lines intended to transmit either telephony or television signals, the filter must show no appreciable response below the pilot frequency. A quartz vibrator is generally capable of vibrating on a number of different modes, each giving rise to spurious dips in the transmission characteristics of the line. The reduction of these unwanted responses to a safe level has involved the design of a crystal element in which the surfaces of the blank are spherically bevelled. These techniques are being further developed so that pilot-stop filters can be designed to operate in the middle of the pass band of a transmission line. Crystals for such applications would ideally show no responses either above or below the wanted frequency. The nature of the mode of vibration of crystals operating at high frequencies makes it impossible to eliminate the many unwanted responses just above the fundamental frequency, but it appears likely that careful choice of the crystal geometry can reduce the activity of these responses to a safe level.

THERMIONIC VALVES.

The trend towards the use of higher frequencies is also reflected in recent developments in thermionic devices. Emphasis has been given to work on special valves of all types, including ultra high-frequency devices, valves for industrial applications and gas-filled valves.

MICROWAVE VALVES.

The best-established microwave oscillator is the cavity magnetron. An experimental form of magnetron for low-power pulsed operation at 10,000 Mc/s has now been produced. This has an anode system of the "rising sun" form within a glass envelope. Coupling to the waveguide is by direct radiation from the anode system through a specially shaped waveguide transformer. A pulse power of about 1·5 kW may be obtained with a voltage of 2·5 kV, and pulses as short as 0·1 μs may be generated without jitter at the pulse start.

Fig. 4.—Robust 80 kW magnetron.

A new and more robust form of higher power magnetron for operation at 10,000 Mc/s has also been produced. Giving a power of 80 kW at a pulse length of 1 μs, it is capable of operating with a rate of rise of voltage of 250 kV/μs. Fig. 4 shows this valve, the special attached magnet and the integral waveguide output system; the complete unit weighs 6 lb.

For use as a high-power C.W. microwave amplifier, a two-cavity klystron for a frequency of 10,000 Mc/s has been developed.* With an output of 2 kW, its efficiency of 32 per cent. is higher than any previously reported for klystrons of this type. Fig. 5 shows the valve installed in its electron beam focusing magnet, part of which is removed to show the klystron itself. The same design principles which have produced this high efficiency are being applied to other valves. A further klystron under development* incorporates more cavities, which result in a higher gain and frequency bandwidth. Valves incorporating the multiple-cavity principle are also being designed for operation at a somewhat lower frequency for communication purposes, with the same advantageous results.

The very large frequency bandwidth of travelling wave tubes is becoming increasingly important for use in multichannel microwave communication. A design of output tube has been established for the 1,700-2,300 Mc/s frequency band, which gives a power of more than 25 W with a power gain of 1,000 and efficiency of 20 per cent. Fig. 6 shows this tube installed in its electron focusing system with input and output connections. Travelling wave tubes can also be designed to give very low noise when used as the input tube to the receiver, and such a tube is under development for the same frequency band. A research programme has also been carried out on the design parameters of high-power travelling wave tubes operating in the 500-1,000 Mc/s frequency band, using a demountable tube and pulse techniques. Peak powers in excess of 10 kW and an efficiency of 30 per cent. have been obtained. The information gained with this experimental equipment will be of particular value in designing valves of such high powers, combined with very large bandwidths, should these be required in the future.

A study* has been made on a high-power pulsed amplifier operating over a wide frequency band, which embodies a number of high-power electron beams projected across two waveguides. This has involved a study of special slow-wave circuits and the development of a suitable electron gun to correlate the performance of a single beam amplifier with the theoretical results.

In microwave valves of the backward wave oscillator type,* power is generated by energy exchange between a wave travelling in a delay line in one direction

* Work carried out on behalf of the Admiralty.

* Work carried out on behalf of the Admiralty.

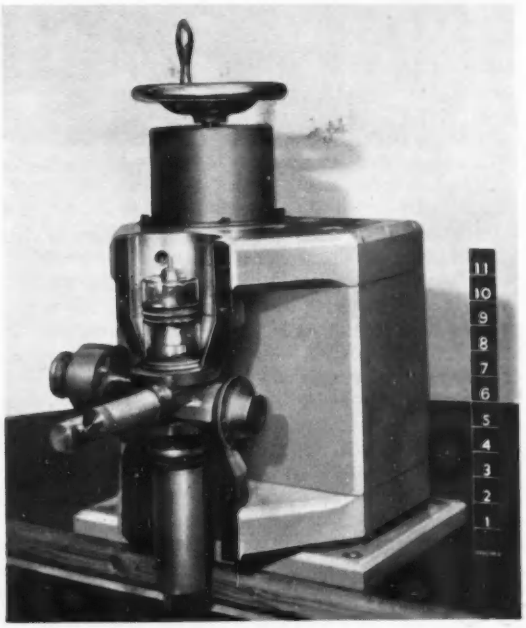


Fig. 5.—10,000 Mc/s two-cavity klystron installed in its electron beam focusing magnet (cut away to show the valve).

and an electron beam coupled to it and travelling in the opposite direction. Such devices are self-oscillators, in which the frequency is determined not by the resonant properties of the circuits but by the velocity of the electron beam, and can therefore be controlled rapidly by change of voltage.

In one class of backward wave oscillator, in which the energy exchange mechanism is similar to that in a magnetron, powers greater than 100 W are produced at frequencies in the neighbourhood of 3,000 Mc/s over a frequency band of the order of 30 per cent., and much higher powers are possible. These may have important uses in communication systems. Another valve of this type, in which the energy interchange process is similar to that in a travelling wave tube, is more suited to low powers such as those required for measurement and receiver purposes. This is particularly suited to operation at the highest radio frequencies, and work carried out at frequencies around 80,000 Mc/s has shown the possibility of generating power of the order of 5 mW over a frequency range of at least 10 per cent. These oscillators are valuable tools for certain research investigations, particularly those into the properties of materials and gases at these high frequencies.

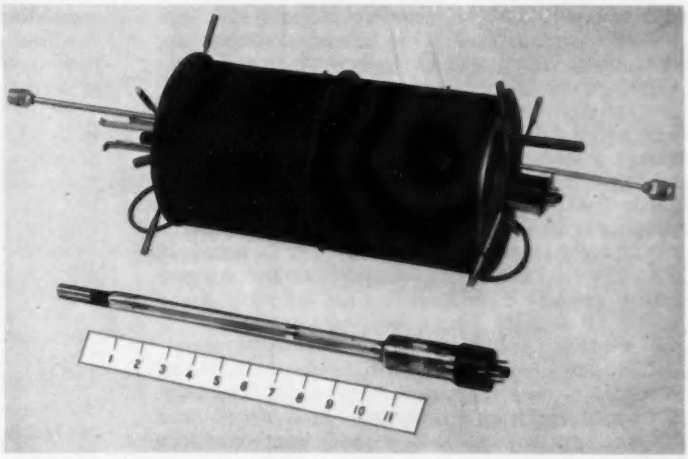


Fig. 6.—Travelling wave tube, installed in its electron focusing system, for 1,700-2,300 Mc/s frequency band.

Industrial Valves.

A range of three forced-air-cooled triodes for R.F. heating, with anode dissipations of 5, 10 and 20 kW respectively, has recently been introduced. In developing these valves, particular emphasis has been placed on their capacity for long and trouble-free operation under onerous industrial conditions, and robust construction techniques have been used throughout. Water-cooled versions of the 10 and 20 kW triodes are also available.

Audio Valves.

A new addition to the range of audio valves is the KT88, a beam pentode with an anode dissipation of 35 W, which may be regarded as a modern, higher powered version of the KT66. The valve is mounted on an octal base, and a button glass seal is used instead of the more common pinch type. This feature enables the high anode loading to be achieved in the relatively small size. Two such valves connected in the ultra-linear circuit can deliver 50 W of audio power output connected in push-pull with auto bias and with a H.T. line of 500 V ; or 100 W output with fixed bias and line voltage of no more than 560.

For even higher power outputs, the maximum allowable anode potential of the DA42 has now been increased to 1,250 V, so that an output of 200 W can be obtained when two valves are used in push-pull under Class B zero bias conditions.

Special Receiving Valves.

A new U.H.F. triode, the A2521, is proving particularly useful as a low-noise R.F. amplifier for frequencies up to 1,000 Mc/s. At 500 Mc/s, it has a noise factor of 9 dB ; at 900 Mc/s the figure is $11\frac{1}{2}$ dB, with a power gain of 10 dB and a bandwidth of 40 Mc/s.

A new disc-seal U.H.F. triode, the E1771, is the latest addition to the well-known range of such valves and gives a useful performance at frequencies up to about 6,000 Mc/s.

Grid Wire for Valves.

When high performance receiving valves (such as those described above), with the conventional grid control, are used in low-noise receiver input stages for amplifying very wide band signals or for operation at frequencies up to 10,000 Mc/s, special attention must be paid to certain details in their construction. In particular, very close spacing must be achieved between the cathode and the grid, the latter being an extremely fine one consisting of ultra-fine tungsten wire wound with a pitch of up to 1,000 turns/inch. A new system of winding the grids enables the wire spacing to be maintained to an accuracy of about 1 per cent., which is many times better than the best achieved previously. These grids are now incorporated in many different valves with conventional glass envelopes for low-noise receiver input stages up to a frequency of about 1,000 Mc/s, and in disc-seal valves for operation above this frequency.

The increased demand for tungsten wires of 0·0004 in. diameter and less has led to the development of new production methods. The cost of diamond-drawing dies for wire less than 0·0004 in. diameter is very high, and it is practically impossible to make them for diameters below 0·0003 in. The problem has been solved by introducing an electro-polishing

technique for reducing tungsten wires to small diameters. The most efficient design was determined for the electrolytic cell capable of producing wires within a specified diameter limit at economic speeds. In addition, the mechanisms for handling these fine wires had to be scaled down, since the breaking load of 0·0004 in. diameter tungsten wire is about 1 oz. and that of 0·0002 in. diameter wire about 0·2 oz. Special equipment had also to be made for measuring the mechanical properties and dimensions of the wires. Those now being produced are within ± 2 per cent. of their objective diameters.

After electro-polishing down to size, many of the wires must be gold-plated before being used for grid-making. The thickness of the gold coating is usually about 0·00002 in., but the special apparatus and technique used permit much heavier plating when required. Adhesion of the gold plate is excellent, allowing the wires to be handled and bent without fear of cracking or flaking.

GAS-FILLED VALVES.

Of the two hot cathode gas-filled valves developed recently, one is a high current xenon-filled rectifier. The maximum rating is 4 amp mean current and 10 kV peak inverse voltage. An enclosed anode construction enables the valve to operate with a high gas pressure. Since the life is determined by gas "clean-up", this high initial pressure ensures a long life. With the introduction of this valve, the Company now makes the highest-current and highest-voltage xenon diodes in the country. These rectifiers are used mainly in the power supplies of B.B.C. and I.T.A. television and radio transmitters, and in the power-packs of R.H. heaters.

The second valve, a new hydrogen thyratron (fig. 7), has been developed* to provide the short-duration pulses of very high power required for radar transmitters. This is the highest-current hydrogen valve available in the world in the high-voltage pulse modulator field.

The operation of this thyratron is simplified by the inclusion of a barretter-replenisher system for gas pressure control, which automatically replaces the hydrogen "cleaned up" during life and compensates for variations in supply voltage and ambient temperature. This device is now fitted in all new G.E.C. hydrogen thyratrons so that their life performance is not limited by loss of gas.

T.R. AND T.B. CELLS.

Other gas-filled devices, which break down readily under the action of radio-frequency electric fields, are used as automatic switches in radar sets to isolate the receiving equipment from the high-power transmitter pulse. Recent work* on these transmit-receive (or T.R.) devices has been aimed at developing cells for working over wide bandwidths to avoid the necessity for tuning.

These wideband cells normally consist of a section of waveguide, closed at the ends by resonant windows and containing a number of tuned elements spaced a quarter of a wavelength apart. Research at both the G.E.C. and the Services Electronics Research Laboratory has shown that the functions of these tuned elements can be separated with advantage and incorporated in separate tubular plug-in cells. Each of these can then be designed with its own optimum gas filling and correct electrode design to fulfil its function. Combinations of the plug-in cells can be used by the radar equipment designer to achieve any desired performance.

For short-range radar sets, the discharge produced in the T.R. devices by the transmitter pulse must be rapidly cleared. A little water vapour in the rare gas filling gives the required clearing, but rapid clean-up of this water vapour in the discharge can lead to short life. Research has now shown that water vapour condensed on an extended surface of metal can be used to maintain constant water vapour pressure within the device over a much longer life than has been previously attained. Such water vapour replenishers have been incorporated in recent plug-in cells.

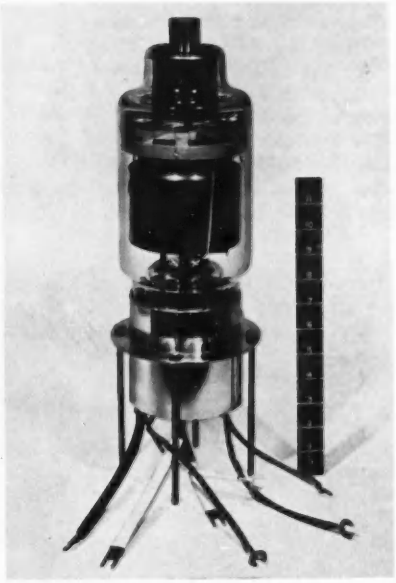


Fig. 7.—VX.3250 hydrogen thyratron.

Seventeen different types of T.R. and T.B. cells are in production or pre-production. A bandpass display system* for tuning broadband T.R. cells is being used as a production tool. The bandpass characteristic is automatically displayed on a cathode-ray tube screen, and enables semi-skilled operators to perform difficult tuning operations. A CV234 oscil-

* Work carried out on behalf of the Admiralty.

* Developed under Admiralty contract on behalf of the Ministry of Supply.

lator is mechanically tuned once every second over a frequency band of 12 per cent., the output being stabilised by a feedback loop on to the oscillator. The reflected wave from the T.R. or T.B. cell on test is separated in a directional coupler and, after detection, is amplified to provide the vertical deflection on the display. The horizontal sweep is supplied by a linear time base synchronised to the wavelength sweep of the oscillator. A plot of reflection coefficient against wavelength is thus obtained, with a presentation accuracy of better than $\pm$ ·01 in reflection coefficient over the range 9·2—10·6 cm.

CATHODE-RAY TUBES.

Increasing emphasis is being placed on developments in cathode-ray tubes for radar and instrument display. For example, two new instrument tubes, 4GPI and LD247, have been introduced to supersede the existing 3½ and 6 in. types. Several important features which have been incorporated make the new tubes suitable for high-quality precision oscillography. Improved spot quality is given by the altered design of the gun and by the use of a plate-glass screen which reduces the "halo" normally surrounding the fluorescent spot. Precautions have also been taken to reduce the interelectrode capacitance, and a high value for the deflection sensitivity has been obtained by employing a single stage of post-deflection acceleration. Four varieties of screen are available : green screen (persistence 100 millisecs.), television white (1 millisec.), blue flash yellow afterglow (20 sec.) and blue screen (persistence 1 millisec.).

A further tube has been developed for use in the recording of very fast single-stroke transient phenomena. This can be used to record photographically phenomena of 10^{-9} seconds duration. By the use of a wave-deflecting system in conjunction with two stages of post-deflection acceleration, a signal plate sensitivity of 0·5 volt per spot diameter is achieved.

Among the improved radar tubes which have also been developed, a 12 in. tube employing a triode gun has given a good performance and, in certain instances, has been preferred to the previously accepted standard radar tube which employs a tetrode gun.

SEMI-CONDUCTOR DEVICES.

Junction transistors are now being produced on a substantial scale for a wide field of applications. For example, in audio-frequency reproduction the low-noise type GET6 transistor has a signal-to-noise performance similar to that of thermionic valves, and is ideal for use as the pre-amplifier in tape recording and record playing equipments. The type GET4 transistor can be used in Class B push-pull output stages to provide output powers of up to ¼ W at low distortion from a 6 volt battery, while an amplifier using a pair of type GET5 transistors will deliver up to 2 W from a 12 volt battery. In the intermediate stages, transistors of types GET3 or GET4 can be used. These will operate satisfactorily in some circuits at frequencies of 1 Mc/s and higher, and have been used successfully in experimental medium wave broadcast receivers.

The type GET5 transistor can handle sharp pulses of current of up to ½ A, and is therefore of great interest in electronic computers where it can be used to operate both ferrite and magnetic drum stores. The type EW57 transistor, which is now in an advanced state of development, will handle higher powers and currents. In a push-pull audio amplifier, an output power of 10 W at low distortion can be obtained from a 12 volt d.c. (typical car battery) supply.

Much of the advanced development work is now devoted to the design and manufacture of junction transistors to operate at frequencies of 10 Mc/s and higher, and to silicon transistors which will work at higher ambient temperatures than germanium devices. In view of the promising results being obtained with high-frequency junction types, work on point contact transistors has been discontinued.

Considerable progress is being made in the development of silicon rectifiers, and peak inverse voltage ratings of up to 400 volts are now being achieved consistently. A general purpose rectifier, type SX632, which has a peak inverse voltage rating of 400 volts, will deliver a rectified current of up to 300 mA in a half-wave rectifier. Devices of this kind have very high rectification efficiency, and more care must be taken in the design of the associated rectifier circuit, particularly for overload conditions, than is necessary with lower-efficiency rectifiers.

There is considerable interest in the possible application of the reverse "breakdown" (Zener) characteristic of silicon junction diodes, and types are being developed for use both as reference voltage sources and as surge limiters (e.g. lightning protection).

PRINTED CIRCUITS AND AUTOMATIC ASSEMBLY OF ELECTRONIC EQUIPMENTS.

The advantages offered by the use of printed circuits in the electronics industry include reduced overall dimensions of the equipment, simplified replacement and servicing problems, the inclusion (within limits) of coils, switches and other components in the circuit printing, the possibilities of automatic assembly and the automatic testing of components and circuits during the assembly stages. Investigations have recently been carried out into the merits and limitations of printed circuits in comparison with the more conventional point-to-point wiring. Further work has been concerned with alternative means of producing such circuits and of testing the printed components manufactured.

Considerable attention has now been given to the possibilities of mechanical assembly for electronic equipment. Most systems designed for this purpose start with a printed circuit as the main support for the other components being assembled. This calls for close collaboration between the designers of the circuits, the components and the assembly machines used. Studies have also shown that it is not econo-

mical to insert all the required components automatically, so that such items as tuning condensers and large electrolytic condensers which clip into position, are still inserted by hand.

An experimental machine designed and constructed for assembling and soldering etched circuit panels of maximum size 12 in. × 6 in. consists basically of three sections. The first, an automatic inserting unit for resistances and other small components, is at present fitted with 24 heads but has provision for 40; it is pneumatically operated and electrically controlled. The second is a hand assembly track, conveyor-fed at the same speed as the rest of the machine, while the third section incorporates the necessary equipment for the automatic cleaning, fluxing, soldering, washing and drying of the assembled printed circuit panel. Work is proceeding on methods of checking components and testing circuits during the time cycle and at the same rate as the machine operates.

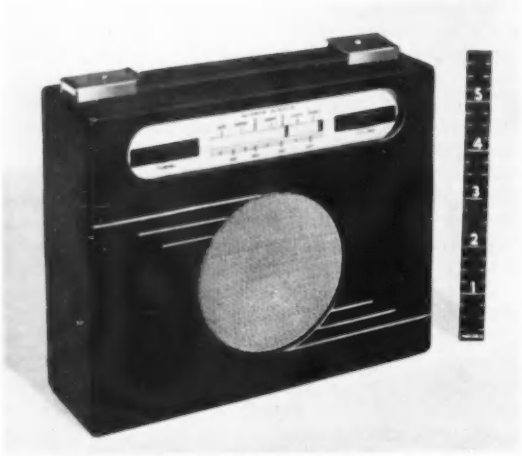


Fig. 8.—Experimental 7-transistor portable receiver.

DOMESTIC RADIO.

Transistor Receiver.

A small experimental portable radio receiver, which has recently been constructed, uses a total of only seven junction transistors. The receiver line-up consists of a self-oscillator mixer stage followed by two 470 kc/s i.f. amplifiers, a transistor detector, audio stage and Class B push-pull output. It is operated from a H.T. line of only 6 volts, derived from two 3-volt torch batteries. The maximum output power is about 150 mW, and the electrical performance is comparable with the usual valve-type portable receiver (fig. 8).

Sound Radio

The home market for broadcast radio receivers continues to be largely influenced by the extension of the VHF/FM system of transmission throughout the country. It is not therefore surprising that the two main introductions in the range of broadcast receivers are of the FM/AM type.

One of these is the BC5645 table receiver with a plastic cabinet, designed to compete with the so-called "Continental" styling with its contrasting colours and ornate embellishment. The other model houses a similar receiver in a compact table radiogram cabinet which incorporates a four-speed record player, catering for all the more common types of recording as well as for talking-book records which run at a speed of 16 r.p.m. This model also meets the increasing call for high-quality reproduction, being fitted with three loudspeakers—a large elliptical speaker at the front with two smaller side speakers.

Portable radios, particularly those with alternative operation from mains and battery, continue to hold and increase their popularity. The new BC4448 follows the general design of the previous "suitcase" type portable receiver, but has more modern lines and includes space for larger batteries.

SOUND REPRODUCTION.

For public address schemes in such places as oil refineries or coal mines, a new pressure-type loudspeaker has been introduced for use in inflammable atmospheres (fig. 9). The unit, which can be used with an exponential or re-entrant type horn, employs completely new principles which entitle it to flameproof classification, and a certificate to that effect (covering Groups I, II and III) has been issued by the Ministry of Fuel and Power. It is thought that this loudspeaker is the only one of its type which is completely flameproof as distinct from intrinsically safe.

The automatic announcing machine (fig. 10) now incorporates an improved track selector mechanism which is driven by a motor with a new form of electro-

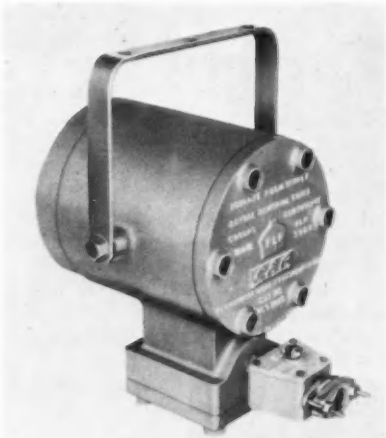


Fig. 9.—Flameproof loudspeaker.

mechanical detent device to provide precise location of the reproducing head on the magnetic tape band. This instrument is finding new applications in the industrial field, wherever a series of pre-recorded messages is used either for the co-ordination of processes or as part of safety precautions.

For exceptionally high quality sound reproduction, a new loudspeaker unit has been introduced as an accessory for use with the metal cone loudspeaker. This unit screws into the centre of the loudspeaker in place of the existing " bung " and is connected across the loudspeaker through a condenser. It has a flat frequency response from 2 to 13 kc/s. Taking advantage of the unequalled bass response and smooth overall response of the metal cone loudspeaker, it adds to the middle and top frequencies, at the same time improving their spatial distribution. The effect is to bring forward the reproduction of the sound and so give an enhanced impression of realism.

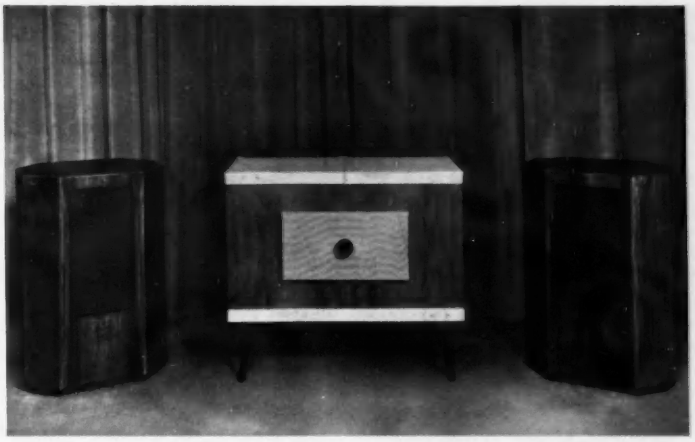


Fig. 11.—Stereophonic sound equipment, comprising amplifier/tape-player console and two identical loudspeaker units.

Following many years of research into stereophonic sound, new equipment has been introduced suitable for stereophonic reproduction in the home, using commercially available tapes. The complete equipment (fig. 11) comprises three units: two identical loudspeaker units and one amplifier/tape player console. The twin-track player unit is connected to two 12 W high-quality amplifiers, with individual controls for tone adjustment and stereophonic balance. The loudspeaker system is made up of metal cone loudspeakers and " presence " units mounted in octagonal cabinets. The special arrangement used gives a pattern of sound distribution which ensures correct stereophonic operation over the widest possible area.

Fig. 10.—Automatic announcing machine.

TELEVISION.

In domestic television, the B.B.C. programme for transmissions in Band I is now largely completed, both as concerns the number of stations and their power, so that problems associated with this Band are now virtually clarified. The introduction of transmissions on Band III raised a new series of problems largely associated with variations in propagation, and these have been further complicated by the programme of extension of the service to provincial stations and by the fact that, in the initial stages, these stations operate on reduced power and often use temporary aerial installations. As a result, the overriding consideration in the design of television receivers has become their performance on Band III reception. During the stage at which the field strengths from various stations are still reduced, reception must be catered for under conditions considerably more onerous than those which will be encountered finally. This situation is further aggravated by the fact that these areas of low signal strength are often found where Band I reception is quite satisfactory. It has therefore become essential to cater for these conditions by providing increased sensitivity in all television receivers. This represents a change from the previous policy of having standard models for service areas with adequate signal strength, and fringe models of higher sensitivity for secondary

service areas which have low signal strength, often with a high degree of interference.

The new principle is reflected in the current range of television receivers. Modifications have also been introduced in the time-base circuits so as to improve performance under conditions of high interference.

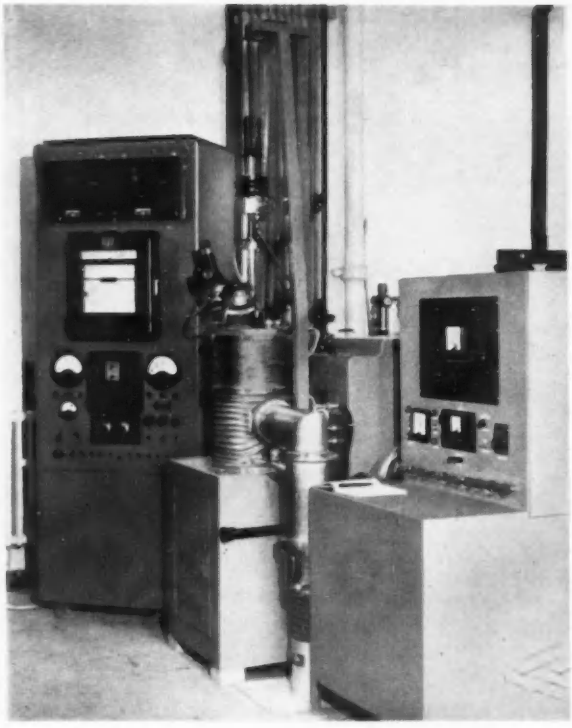
The increasing number of high-power stations in both Band I and Band III has also necessitated greater attention to the problems of cross-modulation. Circuits have been revised to deal with this by incorporating a new long-slope H.F. pentode valve, W729, which is used throughout the new series of receivers in the common I.F. amplifier stage.

A further result of the increased number of high-power stations is that some areas now have a service available from more than one transmitter, and the user may wish to select one transmission or another depending on the propagation conditions. This requirement is now satisfied in the current range of television receivers by incorporating full 12-position turret tuning. The sets are thus equipped for all the channels which have so far been allocated, and extra coils for further channels can be fitted as the necessity arises.

The most popular television receivers are still the 14 and 17 in. rectangular tube models, but there is a growing interest in larger receivers incorporating the 21 in. tube. The new range includes all these types, and the 21 in. table model, BT3251, which is the most recent addition, is fitted with twin loudspeakers for improved quality of sound reproduction.

Colour Television.

In preparation for a recent conference on colour television systems, the International Radio Consultative Committee studied world developments in this field. As a part of this study programme, a demonstration was arranged in London by the Radio Industry Council in which colour television signals were received from the B.B.C. transmitter at Alexandra Palace. The G.E.C. receiver, one of several provided for the demonstration, was an experimental model. The performance of this receiver was among the best obtained during the test. Although the circuits used were broadly in line with the requirements of a practical domestic receiver, considerable simplifications are still possible.



In the January, 1956, issue an illustration was shown of a single crystal of silicon weighing 100 gm. and having a uniform N-type resistivity of 20 ohm-cm. throughout its bulk. This illustration shows a versatile crystal growing machine which has been developed for producing large single crystals of both silicon and germanium with accurately controlled properties.

The Year's Progress

Heating and Ventilation Engineering

The passage into law of the Clean Air Act has led many users of heating equipment to re-examine the advantages of electric heating, which are not confined merely to freedom from smoke, dust and fume. In space, industrial and process heating, electric power offers high efficiency, precise control, immediate response and convenient application of heat when and where it is required.

These advantages apply particularly to electric furnaces, most of which are produced for metallurgical applications. The present-day trend towards larger installations calls for bigger furnaces—indeed, continuous furnaces over 400 ft. in length are being built. A shortage of skilled operators increases the importance of precise instrumentation and control combined with advanced forms of mechanisation. The problems to be solved are essentially those of handling materials at very high temperatures.

Vacuum furnaces are being increasingly used. One example, now in production, is a 120 kVA graphite resistor furnace (fig. 1) designed to operate at a maximum temperature of 2,000 deg. C., and a vacuum better than 10^{-5} mm. mercury. It is used for the degassing of metals with affinities for such gases as hydrogen and nitrogen, which affect the properties of the metal adversely, and for brazing, sintering and other treatments. The charge space is approximately 9 in. in diameter by 12 in. deep. This furnace is considerably cheaper than one of similar size employing induction heating.

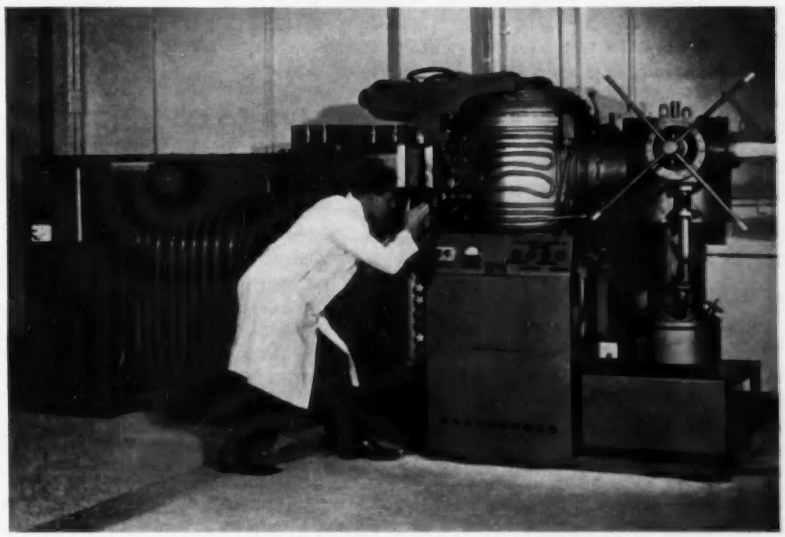


Fig. 1.—120 kW graphite resistor vacuum furnace.

Some of the work on atomic energy and guided weapons has called for furnaces capable of operating at extremely high temperatures. An outstanding example is a unique resistance furnace, capable of reaching a temperature of 3,000 deg. C., which has been installed at the Atomic Energy Research Establishment, Harwell. Designed in association with the Establishment, it has a useful working volume of 3·25 cu. ft. and can take a charge weighing 240 lb. The heating element consists of six graphite plates arranged in hexagonal plan form, which permits the greatest possible use of space for the charge. The furnace chamber and hearth floor are also built up of graphite plates, thermal insulation being provided by carbon black powder. Fig. 2 shows the heating elements and furnace chamber during erection. Power is derived from a three/six-phase step-down transformer. The primary voltage is 415 volts (50 c/s), and the secondary voltage is continuously adjustable on load between 5 volts minimum and 20 volts maximum. The maximum continuous input to the furnace is 200 kVA at 19·5 volts. During commissioning, the furnace attained a temperature of 3,000 deg. C., starting from cold, in about six hours, with a mean input of 150 kVA. The steady state losses at maximum temperature are about 75 kW. For temperature control, a total radiation pyrometer sighted on one of the elements actuates a proportional relay which adjusts the secondary voltage to balance heat losses and energy input. The furnace is operated with an atmosphere of pure argon to protect the charge and elements against oxidation. At a pressure of 5 p.s.i.g. the gas is continuously circulated by a Rootes type blower in a closed loop consisting of the vacuum-tight furnace and a gas purification train. The

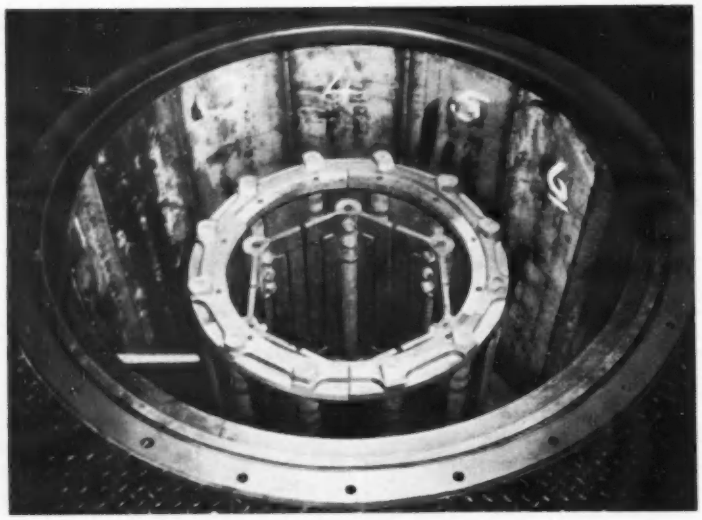


Fig. 2.—The graphitisation furnace at Harwell in course of erection. (Photograph—Atomic Energy Research Establishment.)

principal impurities contaminating the argon are CO, O_2 and H_2, and the purification train keeps the level of these below 500 p.p.m. Before filling with argon, the furnace is evacuated to a pressure of 10^{-2} mm. mercury by a two-stage vacuum pump.

The furnace has been built to assist experimental studies of the making of graphite, a material which will be used extensively as a moderator in nuclear power stations. The installation provides many advantages over the conventional method of graphitising, since it enables the purity of the atmosphere and the temperature of the charge to be closely controlled. Moreover, the rate of temperature rise is not affected by the graphitisation process itself, and a quicker turn-round time can be obtained with a power consumption no higher than that of the conventional self-heated bed type of furnace.

Among the more conventional uses of electric furnaces is their application to the hardening of steels by the three well-established gaseous processes of carburising, nitriding and carbo-nitriding. As the number of special steels available grows, so do the problems connected with the surface-hardening of these materials. In addition, the requirements are becoming increasingly exacting for the control of atmospheres in the furnaces used. Efforts are being directed towards achieving automatic control of these atmospheres by automatic gas analysis. A continuous carbo-nitriding furnace, with a rating of 126 kW, and a heated length of 16 ft. 6 in., giving temperatures up to 900 deg. C., has now been installed in the Citroën Motor Works in Paris as part of the production line. It is believed to be the largest in Europe. This installation includes a carbon gauge for checking the quality of the carbo-nitriding atmosphere.

The trend towards greater mechanisation in industry generally has led to an increasing use of high-frequency heating in many manufacturing processes. Equipment of this type is now regarded as one of the machine tools in a production line and not merely as a furnace. The applications of high-frequency heating are mainly in the field of metal treatment, such as hardening, brazing and soft soldering.

An example of automatic operation is provided by the new high-frequency heater recently produced for hardening refrigerator compressor shafts, which handles 60 components an hour and is fully automatic. The generator is the new 7 kW induction heater, shown in fig. 3, which is more compact than previous induction heaters of similar rating. It operates at a nominal frequency of 500 kc/s and the output is smoothly variable from zero to full power. This set is designed with a view to simplicity, reduced cost and increased ease of maintenance.

Applications of radiant (infra-red) heating are widening in scope, particularly since the choice of using either sheathed-wire elements or lamps as the heating units is available. One new field of application for radiant heating is the treatment of plastic fabrics and sheeting. Equipment is now available for the setting of nylon and "Terylene" fabrics by radiant heating as a continuous process, with temperature control. The equipment has the advantages of cheapness and speed in comparison with other methods. Being light in weight, it can be suspended over existing stenters without major

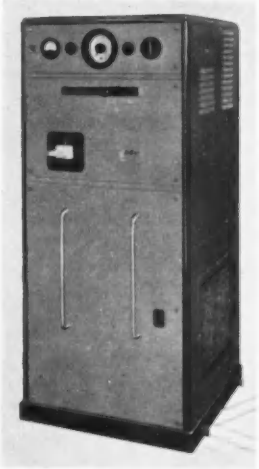


Fig. 3.—7 kW H.F. induction heater. It occupies a floor space of less than 6 sq. ft. and is 5 ft. 4 in. high. Supports for a work table are fitted in front.

structural alterations, and its small size means a low capital cost. The short treatment time avoids discoloration of the fabric by oxidation. The recommended heat source is the radiant reflector panel with sheathed-wire elements.

Reflector heaters are being used for the curing of polyester resins in glass fibre-polyester resin mouldings, one application being in the production of " Fibreglass " reinforced plastic bodies for sports cars.

AGRICULTURAL HEATING.

During the wet summer of 1956, the need for a drier to deal with a crop after combine harvesting was emphatically brought home to farmers, even

Fig. 4.—The tray-type grain drier.

those with only a small acreage under grain. In the past, the simplest and least expensive drier for the small farmer was the platform type which deals with grain in sacks. With the ever-increasing need to save labour on the farm, there is a growing preference for drying grain in bulk, and to meet this requirement, a small and inexpensive tray drier has been developed. As with the platform driers, the farmer is supplied with the essential components, which are then assembled on the site. The tray is of steel, with a perforated floor, and is installed at an angle to facilitate loading and unloading, the grain remaining stationary while being dried, after which it can easily be emptied. This drier (fig. 4) employs a fan and heater unit similar to that used for platform models.

A new range of infra-red warmers for animals, principally piglets and poultry, has also been introduced. Using the Osram 250 W infra-red industrial lamp as a heat source, the warmers are completely insulated, the lamp being housed in a strong " Fibreglass " shade. This eliminates the need for earthing,

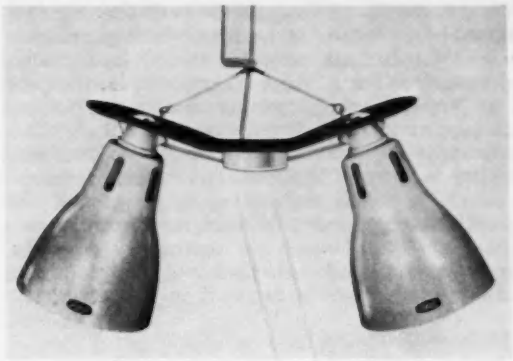


Fig. 5.—Infra-red warmers for animals.

which can be a major and costly procedure in isolated farm buildings. The single-lamp model provides adequate warmth for 75 chicks or a litter of 6 piglets, and the two-lamp warmer (fig. 5), consisting of two of the single-lamp units mounted in a " Perspex " strip, caters for 150 chicks or 12 piglets.

The existing dull-emitter warmer fitted with an unbreakable sheathed-wire element has now been made available with a pilot lamp to attract the livestock to the warm area (fig. 6).

SPACE HEATING.

Sheathed-wire elements are also used in the overhead radiant heater produced for short-period or local heating. This equipment consists of a trough reflector made of aluminium sheet with an anodised finish, shaped to give a wide distribution of radiation, and heating elements which are " hairpin "-shaped, with the ends passed through a sheet of insulating material, fixed at one end of the trough to a terminal

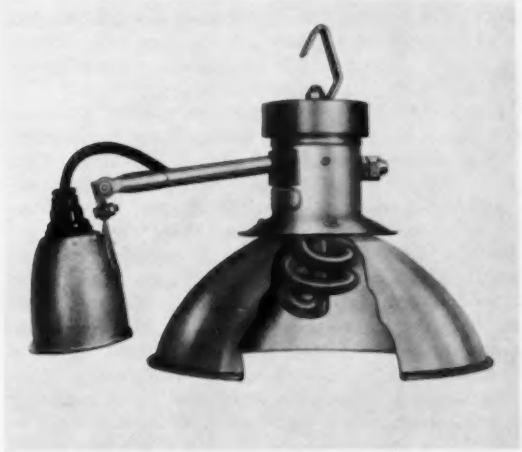


Fig. 6.—Dull-emitter warmer with pilot lamp.

compartment. Two loadings are available : the two-element heater is rated at 3 kW and the single-element at 1½ kW. In both cases the trough is the same, its dimensions being 3 ft. 4 in. long, 10½ in. wide and 3⅛ in. deep. The heater can be mounted as a pendant fitting or by wall brackets from two saddle brackets on the back of the trough. These heaters have been installed in stores as local heaters, and in churches and halls. A 36 kW installation in a village hall was tested last winter and performed satisfactorily when used for a wide variety of community activities. Even in severe weather the hall could be pre-heated to a comfortable level in two to three hours.

TESTING CONTACTS.

A new machine has been developed to test the behaviour of switch contacts. When making and breaking currents of 20 A or so, contacts tend to stick together, and it is necessary to know the probable strength of such welds in order to design thermostats to give reliable and safe operation.

The forces involved, and their dependence on current and power factor, have been established. The new apparatus enables a continuous record of weld strengths to be obtained over a large number of operations. The contacts under test are closed by a spring and opened by an electro-magnet opposing the spring. The current in the electro-magnet is controlled by a variable resistance, the slider of which is moved by a driven shaft through a magnetic clutch. When the contacts open, the magnetic clutch is de-energised and the electro-magnet current is reduced to a small value necessary to keep the contacts open. After a delay of about one second the electro-magnet current is cut off altogether, the contacts close and the sequence is repeated.

A record of the current in the electro-magnet is kept by a recording milliammeter, the chart of which is moved in steps to correspond with the operation of the contacts. The current recorded by the milli-ammeter is related to the weld strength by direct calibration of weighted contact arms. By this means it is possible to obtain the distribution of weld strengths over a long period of operation.

VENTILATION.

The latest addition to the range of electric motor-driven axial-flow fans is the smallest fan so far made by Woods of Colchester Ltd. This is a very compact 400 c/s axial-flow fan and has been produced for air-borne applications. Intended chiefly for cooling electronic apparatus, it has been designed to comply with the DEF.5000 and K.114 specifications. A downstream guide vane fan, with an impeller of 2·4 in. diameter, it is less than 4 in. in length and weighs under 1 lb. The integral construction has enabled remarkably good efficiency to be achieved at this low weight.

The motor, which was developed specifically for the application, has a diameter of only 1·6 in. and is available in two versions. With a four-pole design running at 11,000 r.p.m. and consuming only 15 W, the fan will move 30 c.f.m. at a static pressure of 0·8 in. water gauge. With a two-pole motor the speed is 23,000 r.p.m. and the fan output of 60 c.f.m. at a static pressure of 3 in. water gauge is exceptionally high for the size and weight of the unit.

The guide vanes and motor carcase are integral with the casing, the whole being a one-piece pressure die-casting in L.M.6 light alloy. The impeller is a nylon and mica filled phenolic moulding with aerofoil section wings, running with a tip clearance of 0·020 in. The totally enclosed squirrel cage induction motor is rated for 1,000 hours continuous operation in an ambient temperature range of −40 to +80 deg. C. The temperature rises of windings and ball bearings are unusually low owing to the efficient cooling provided by the integral guide vanes.

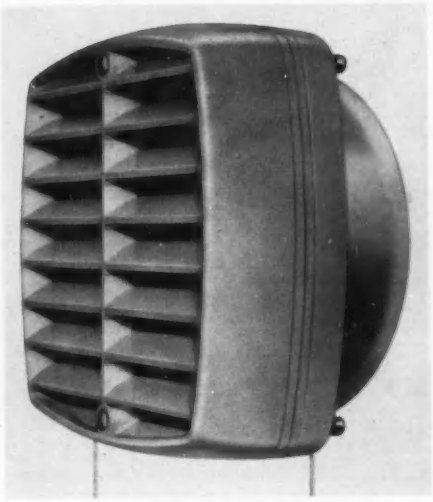


Fig. 7.—The square grille outlet of the new Xpelair fan (6 in. model).

The introduction of a built-in iris shutter in the Xpelair domestic window fan has now been followed by a re-styling of the design. Backdraught being no longer a problem, it has been possible to replace the circular outlet baffle, hitherto characteristic of all window fans, by a neat outlet grille, with economy in cost. Generally square in shape with curved sides, as seen in fig. 7, this is inconspicuous and compact. It projects very little from the fixing surface and fits well with architectural requirements.

With the improved design has come a new model with a 6 in. fan (125 c.f.m.), suitable for domestic kitchens and rooms of similar size. This is moulded in ivory acrylic plastic, with an iris shutter of contrasting black phenolic laminate. The 7½ in. (250 c.f.m.) and 9½ in. (500 c.f.m.) models are now moulded in black phenolic material.

The 6 in. size uses the new two-pole shaded-pole motor (described later), in this instance running at 1,850 r.p.m. to secure minimum noise level at its

rated output. The iris shutter remains unchanged, being linked with an inbuilt fan switch and operated by two nylon cords, but two new installation facilities have been incorporated. For brick and similar walls provided with a square hole, neat, robust wall plates, while remaining permanently in place, permit the removal of the fan for servicing. For shuttered windows of the type common in hot climates, an outer clamp plate limits the projection to only $\frac{3}{4}$ in. from the window pane.

Apparent flickering in room lighting caused by the rotating blades of ceiling fans can prove very irritating and distracting. One method often adopted to reduce flicker is to arrange the lighting fittings below the level of the fans, but this is not always possible or even desirable. Investigations were therefore made into the possibility of using a transparent material and these have resulted in the satisfactory production of fan blades which reduce the flicker very considerably and incidentally improve the appearance of the fan. The material used is eminently suitable for service in the tropics and can be tinted in translucent colours, such as "ice-blue", to meet customers' requirements. At present these blades are available only for the small ceiling fans and are being offered as an alternative to metal blades for the 36 in. "Snipe" fan.

Fig. 8.—Aerofoil 9½ in. fume cupboard fan, cut away to show the overall polythene coating.

The metal-bladed desk fans introduced some 12 months ago have been well received. Since their introduction, however, a demand has arisen, particularly in the Far East, for more positive guarding of the blades, so that they cannot be touched accidentally. After much experimental work, a close mesh guard has been produced which gives full protection. The guard completely encloses the blades both back and front so that even a child cannot touch them, while the standard air flow is maintained.

The established method of protecting Aerofoil fans from corrosive gases by coating them with polythene has been applied to three new sizes, 6, 7½ and 9 in. diameter, designed for fume cupboards. The Aerofoil design has advantages for fume cupboard extraction, since its cylindrical shape and axial air movement enable it to be inserted directly into straight ducting. Exhaust systems can then be made simpler and more compact, with minimum resistance to air flow.

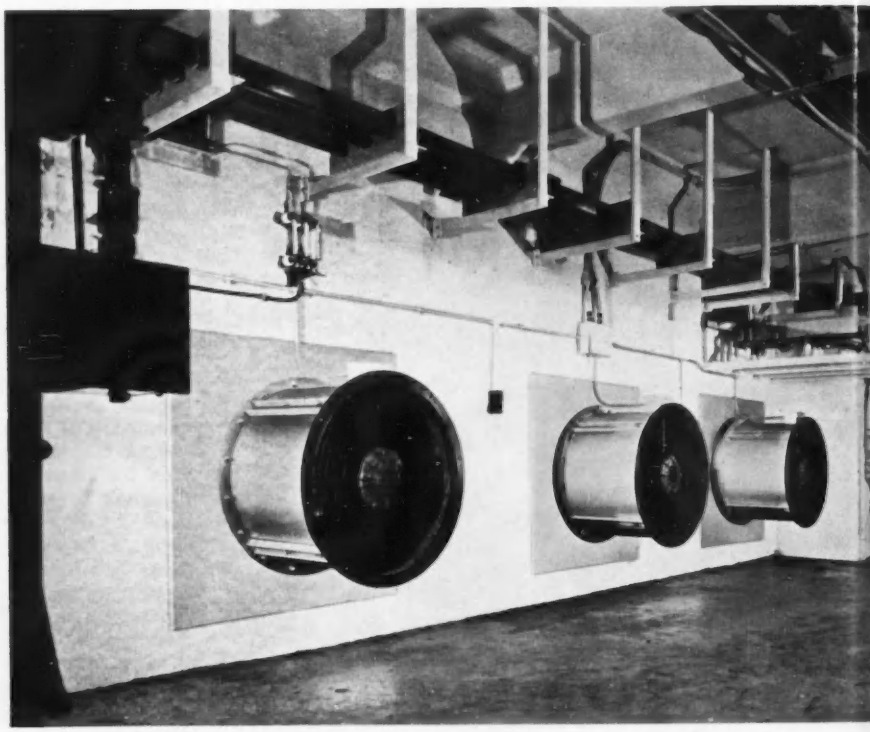
The $\frac{1}{32}$ in. polythene coating effectively protects the entire fan inside and out. The motor and casing are hermetically sealed in a covering which is highly resistant to most corrosive reagents. When polythene is applied to concave surfaces of small radius, there is normally a problem of poor adhesion. This problem has been overcome by using a perforated steel fan casing and coating it on both sides. Polythene passes through the perforations, joining the inner and outer coatings, as if by a large number of rivets, so that the metal is completely sheathed within a homogeneous double skin (fig. 8).

Both the smaller sizes are driven by the new two-pole shaded-pole motors, and the largest size by a capacitor motor. All the motors are fitted with a breathing tube with access to clean air. The impellers are phenolic mouldings. Studs covered with "Neoprene" caps resiliently support the fan on brackets, and connectors moulded in "Neoprene" are supplied for connecting the fan to the fume cupboard and to ducting.

In the search for a high-speed fan motor of small size and low cost to drive small propeller, axial-flow and centrifugal fans, a successful two-pole shaded-pole design has been evolved which makes full use of the possibilities of machine winding on plant developed and built at Colchester. With this type of motor the theoretical background is not yet adequate to ensure the best balance between efficiency, stable speed regulation, good starting and noise level. A development programme was therefore undertaken in which the proportions of shaded section, air gap, rotor resistance, shading loop area and shape, and rotor skew were studied experimentally.

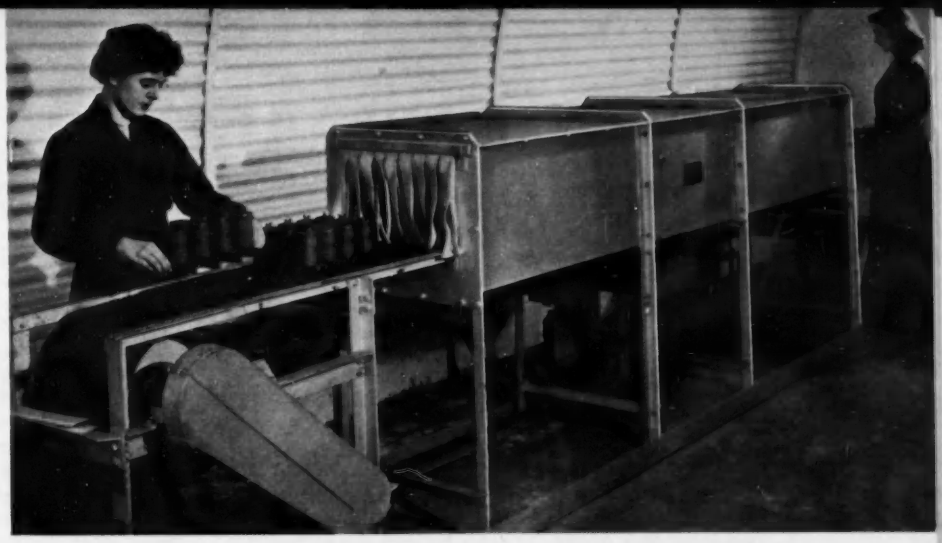
Two sizes are now in production, one with a 2¼ in. stator giving 2 to 5 W output and the other, with a 3 in. stator, 12 to 25 W output—both notable performances for their size. Two forms of squirrel cage rotor are used, one with an aluminium cast cage giving maximum output with a speed of 2,700 r.p.m., and the other, cast in zinc base alloy for increased resistance, giving very smooth speed control with a top speed of 2,400 r.p.m. At the other end of the scale, a new 16 in. diameter 40 b.h.p. induction motor has been added to the range of power equipment for Aerofoil axial-flow fans.

Heating and Ventilation Engineering



Aerofoil single-stage 38 in. fans for generator cooling at the steelworks of John Summers & Co. Ltd.

Aerofoil two-stage 19 in. fans supplying air for conveying tobacco through meshing machines at the London factory of Godfrey Phillips Ltd.



A continuous electric oven for curing resin-impregnated paper elements for fuel oil filters at the works of Cooper's Mechanical Joints Ltd.

Storage heating with Nightstor heaters has established itself as an economical means of ensuring comfort, and therefore promoting efficiency, in business and industrial premises.

Vertical furnaces for annealing bright steel strip at the Courtybella Works of the Whitehead Iron & Steel Co. Ltd., the largest installation of its kind in Europe.

Research

This section contains items from the Research Laboratories' programme that have not been covered elsewhere in this Progress issue.

LAMPS AND LIGHTING.

Impurities in Incandescent Lamps.

If the best performance is to be obtained from the modern gas-filled lamp, the total impurity level in the argon-nitrogen gas-filling must be kept down to a few parts per million. The impurities most detrimental to the performance of filament lamps are water vapour and carbonaceous gases and vapours, particularly carbon dioxide. The concentrations of such materials, while always low in a finished lamp, vary with changes in the manufacturing conditions. There is also a tendency for the concentration level to decrease during the life of the lamp. It is a common practice to keep a check on the impurity level during manufacture by noting the colour and form of a Tesla-excited discharge in the filling gas. By this means, the skilled observer can readily detect changes in the processing conditions.

Recently, more precise meaning has been given to this procedure by studying the spectra of the different types of discharge observed. It has been found that the spectra are in the main from CH, CN and N_2 molecules. CH is frequently present in newly-made lamps of normal quality and is associated with residual traces of carbonaceous matter and water vapour. As the lamp is burnt, the CH bands, if present, disappear in a few hours and give place to CN emission. The appearance of CN shows the continued presence of carbon compounds which clean-up more slowly ; these ultimately disappear to give place to the spectra of molecular nitrogen. This sequence is illustrated in fig. 1, which shows the spectrum for a single lamp at three stages during its life.

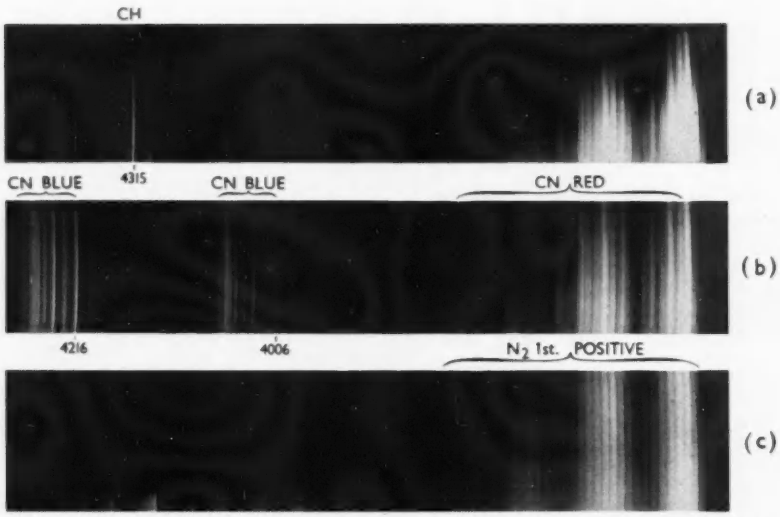


Fig. 1.—The spectrum for a single incandescent lamp at three stages during its life.

(a) Newly-made lamps, showing CH bands.

(b) Shows development of CN bands and disappearance of CH bands after a period of burning.

(c) The spectrum after an extensive burning period shows the disappearance of the CN bands and reveals the N_2 spectrum.

White Paint for Integrating Spheres.

The total light output of electric lamps and other light sources is usually measured in photometric integrating spheres. Provided the inner surface of the sphere is matt white, a small area of this surface (screened from direct light from the lamp) will, theoretically, have a photometric brightness proportional to the total luminous flux from the lamp.

The white paint used for coating such integrating spheres must fulfil several requirements if high accuracy of measurement is to be achieved. It should be non-selective, have a perfectly diffusing matt surface, a reflection factor between 85 and 90 per cent. and be free from change in spectral characteristics with time. In the past, zinc oxide with gelatine binder has been one of the paints used for this purpose, but it has been found that this pigment absorbs appreciably in the ultra-violet and near u.v. regions and the gelatine binder tends to become yellow with age.

With the need for greater accuracy in the measurement of light output and chromaticity of discharge lamps, particularly fluorescent lamps of all colours, there is a growing requirement for better integrating paint. Investigations have, therefore, been proceeding

into the possibility of developing paints with improved characteristics. Barium sulphate has been found to have neutral spectral reflection characteristics throughout the visible spectrum and extending into the near u.v. region. This material has been used with carboxymethyl-cellulose (C.M.C.) as binder, the pigment-binder ratio being about 1 to 5 per cent. An alternative binder which has so far proved satisfactory is polyvinyl-methylether maleic anhydride copolymer (P.V.M.) used in the same ratio as the C.M.C.

In order to minimise errors due to the light absorption of lamps which have blackened slightly during life, it is necessary in some instances to depress the reflection factor of the paint. This adjustment is made by the addition of an accurately-determined quantity of carbon black which reduces reflectivity uniformly throughout the spectrum.

This paint is sprayed on to a priming coat of white cellulose paint which forms a permanent undercoat. The top coat can easily be renewed at regular intervals since the barium sulphate paint is easily washed off with water.

Relative Brightness of Mercury and Sodium Sources.

Research into the relative discomfort glare of different light sources[1] has continued, and a formal comparison between a mercury and a sodium street-lighting installation has now been made.

In the laboratory experiments, when a mercury source of high luminance (20,000 ft. L.) is compared with a similar sodium source of the same measured luminance, over 80 per cent. of observers judge the mercury source to be brighter. The luminance of the mercury source must be reduced to about 0·3 that of the sodium before observers judge them to be equally bright. At very low levels of luminance, the well-known Purkinje effect is observed and, in the region of 0·001 ft. L., about 80 per cent. of observers again consider a mercury source brighter than a sodium source of the same measured luminance. At levels between these two extremes, observers make their judgments more in accordance with the internationally-agreed photometric scale; that is, they find on the whole that mercury and sodium sources of the same measured luminance appear to be equally bright. There is, however, some evidence that, in the region of 0·5 ft. L., the standard photometric scale underestimates the apparent brightness of a sodium source somewhat, so that it appears to a majority of observers to be brighter than a mercury source of the same luminance.

These experiments indicate that the standard photometric scale is not applicable to sources of high luminance and that observers tend to become " blue-sensitive " as the luminance is increased, in a manner similar to the well-established " blue-sensitive " effect observed at very low levels.

In the formal street-lighting test, observers were asked to compare mercury and sodium installations, similar in all respects except the colour of the sources. While most observers agreed with the photometer that the road surfaces were equally bright, 80 per cent. found the mercury installation to be more glaring than the sodium and over 80 per cent. judged the mercury lanterns to be brighter than the sodium. When asked to state a preference for either the mercury or the sodium installation, however, the observers were not so biased, 35 per cent. voting for mercury and 65 per cent. for sodium. This indicates that glare is not the dominant factor in deciding which installation is to be preferred, since some observers voted for the mercury installation even though they found it more glaring.

Among ordinary road users, the preference for sodium street-lighting compared with mercury is rather greater than found in the formal test. This is because most sodium installations are post-war while the majority of mercury street-lighting is pre-war and not so generously planned; casual observers are therefore often comparing good sodium with mediocre mercury installations. In addition, mercury lanterns, even of modern design, do not produce quite such a high level of illumination as sodium lanterns although their maximum intensity is much the same: this factor alone would cause a small majority of road users to find mercury installations more glaring and tend to prefer sodium lighting.

Inspection of Ampoules.

One of the more difficult inspection problems in the pharmeceutical industry arises in the filling of ampoules containing liquid, usually for hypodermic injections. Small foreign particles which can enter or be formed inside the ampoule during the filling, sealing and sterilising operations have to be detected at the final inspection. These particles are minute and often transparent, so they are hard to detect. To overcome this difficulty, a system[2] has been devised in which the normal mechanical presentation of the ampoules to the inspector is achieved under special lighting and viewing conditions.

In order to see the foreign bodies, it is necessary to rotate the ampoule rapidly. This causes the liquid to swirl around inside, carrying the particles around in suspension. The conditions of rotation are, however, critical, since no bubbles must be drawn into the liquid from the air or from gas present in the ampoule. If formed, such bubbles could easily be mistaken for a transparent foreign body and, if there were too many, mask the particles being sought.

In the apparatus, the ampoule holders are mounted on a moving belt, and each is presented in turn in front of the inspector. Each holder is specially designed so that the axis of rotation of the ampoule coincides with that of the holder, thus avoiding the formation of bubbles. A rapid rotation of each holder is followed by a slow counter-rotation during inspection, so that bodies moving in one direction can be differentiated from any marks in the ampoule itself.

After experimenting with many sources of visible and other radiation, it was found that the monochromatic light from a 60 W SO/H sodium lamp revealed the foreign objects best. The source was so mounted as to avoid reflections in the glass walls of the ampoule,

which is viewed against a dead black background obtained by reflecting a matt black surface in a shiny black surface. This arrangement gives a blacker background than the conventional single matt black surface. Foreign bodies are then seen as bright objects against the black background and are easily detected.

An experimental apparatus of this type is now being tested in a pharmaceutical laboratory and shows every sign of being satisfactory.

Aircraft Carrier Mirror Sight Landing Aid.

Safe landing on an aircraft carrier demands, among other things, that the aircraft be brought in at the correct angle relative to the horizontal while aiming at the correct point on the deck in order to hook up on the arrester wires. If the angle of approach is too high there is a risk of damaging the undercarriage on landing; if too low there is a risk of striking the "round down", particularly if the ship is pitching heavily.

The mirror sight (fig. 2), now used extensively on British aircraft carriers, provides a sensitive indication to the pilot of his correct approach path. It consists of a large aluminium mirror in which the pilot sees the bright image of four "source" lights mounted some 180 ft. astern of the mirror. On either side of the mirror are mounted a number of "datum" lights which mark a horizontal through its centre. If the pilot is on the correct approach path he sees the image in line with the datum lights; if above his correct path the image appears above the datum line and vice versa. By adjusting his altitude so that the image remains centred on the mirror, the pilot can bring in his aircraft on the correct approach path to within a fraction of a degree. The mirror is curved in plan so that the indication can be seen continuously from the circuit round to the point of touch-down.

The existing mirror sight complete with datum lights is some 20 ft. wide and is mounted on a special platform over the side of the ship. The size of this whole equipment has aroused criticism, and the Research Laboratories are now engaged in studies aimed at reducing the size of the device while maintaining at least as good a presentation. New datum lights have been designed using special 300 W lamps and giving a light distribution which is such that only three lights instead of seven are required on each side of the mirror. These, in conjunction with a smaller mirror, will reduce the overall size of the equipment to about 12 ft. New source lights, to operate with the smaller mirror, have also been designed. Consuming only 1,200 watts against 8 kW used at present, these avoid "floodlighting" the ship's side at night.

Further work is in progress to explore the possibility of designing an indicator which is even simpler and smaller so that no platform would be required.

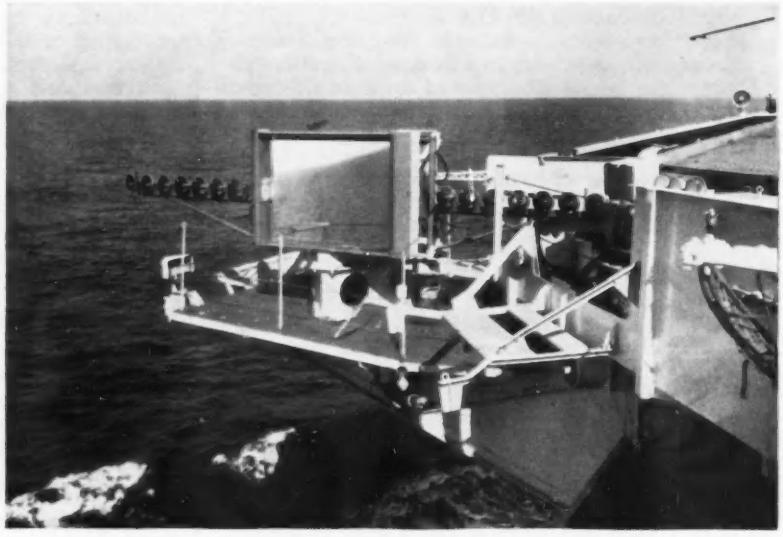


*Fig. 2.—Mirror sight landing aid with G.E.C. datum lights.**

TELECOMMUNICATIONS.

New Ferroelectric Ceramics.

A range of ferroelectric ceramics has been developed comprising solid solutions of sodium niobate with either cadmium or lead niobate, in which pairs of sodium atoms are replaced by one cadmium or lead atom. The properties change progressively with composition up to a limit of some 25 per cent. replacement. The saturation polarisation is about 18μC/cm.^{2} (micro-Coulombs per square centimetre) for the cadmium material and 10μC/cm^2. for the lead material, with coercivities of 10 kV/cm. and 15 kV/cm. respectively.

After polarisation, both materials show an electromechanical activity comparable with that of barium titanate with the advantage of an appreciably higher maximum permissible operating temperature. The new materials are therefore likely to be used in the manufacture of any kind of transducer which requires a piezoelectric material, particularly in applications where it is necessary to extend the operating temperature above 100 deg. C., the upper limit for barium titanate.

In the better known ferroelectric materials, there is

* Reproduced by permission of the Controller, H.M.S.O.

considerable uncertainty (which cannot be resolved by experiment) concerning the influence of packing conditions in the crystal lattice on the structural changes which occur at the Curie temperature. In the niobates, the structural changes which occur are complex; some of them are linked with the Curie temperature and are directly associated with the electrical properties and with the ferroelectric or antiferroelectric nature of the material.

For the three solid solution families formed by sodium niobate with potassium, cadmium and lead niobates, the Curie temperature does not depend on the size of the replacement atom. Other structural changes which occur are directly associated with space conditions in the lattice and the relative size of replacement atoms, but have no direct influence on the electrical properties and transition temperatures.

Microwave Ferrites.

The discovery of the gyromagnetic behaviour of ferrites at microwave frequencies has made many new devices having non-reciprocal properties available to the microwave engineer. All involve the introduction of suitable pieces of ferrite material into the waveguide system and, to avoid dissipation of energy, the ferrite must be substantially free from dielectric loss. A microwave ferrite is thus primarily a magnetic material with unusually high resistivity.

The practical materials which have been developed so far are based on either magnesium-manganese or nickel and nickel-zinc ferrites. With the latter, particularly, the resistivity depends critically on the departure from stoichiometry of the composition, firing temperature and furnace atmosphere.

For most applications at low microwave frequencies, it is necessary to use ferrites of low saturation magnetisation. Replacing iron in the composition by a non-magnetic element such as aluminium allows the saturation magnetisation to be controlled within a wide range. In practice, however, a limit is set by the lowering of the Curie temperature which also occurs, so that suitable compromises must be found to satisfy practical requirements. Some magnesium-manganese aluminium ferrites suitable for resonance isolators in the frequency range 1,700-2,300 Mc/s have been successfully prepared.

The measurement of the dielectric and magnetic properties of ferrites at microwave frequencies presents problems of particular difficulty. One of the most promising techniques now under development is to introduce small specimens into suitable positions inside a resonant cavity and then to observe the resultant small changes in the resonant frequency and Q. By applying a steady magnetic field, the phenomenon of ferrimagnetic resonance can be studied.

Owing to the polycrystalline nature of the material and the anisotropy of the individual crystallites, the width of the ferrimagnetic resonance curve may be considerably broadened. To gain a better understanding of this effect, a study of single crystals of ferrite has been instituted.

Computation of Crystal Admittance.*

The use of a digital computer makes it possible to solve many problems which, although basically simple, involve a prohibitive amount of numerical computation. The type of problem that is particularly suited to a computer is one in which the function to be evaluated involves several parameters whose values have to be changed systematically over large ranges. One such problem, which has recently been handled by the G.E.C. Computing Service, is the calculation of the input admittance of a coaxial type silicon crystal diode.

The essence of the problem is to transform the admittance representing the rectifying point contact of the crystal through three lengths of transmission line of different characteristic impedances. The basic problem is therefore quite simple—three successive applications of a well-known transformation equation occurring in the transmission line theory. The admittance representing the point contact is equivalent to the parallel combination of a video resistance (R) and a barrier capacitance (C) in series with the spreading resistance (r). It was desired to compute the input admittance at 40 frequencies in the range 2,000-18,000 Mc/s for the following values of r, R and C:

R: 3,000 (1,000) 7,000 ohms.
r : 10 (10) 40 ohms.
C: 0·075 (0·025) 0·175 pF.

This meant applying the transmission line equation 12,000 times to obtain the 4,000 complex numbers, representing the input admittance for all possible combinations of R, r and C at all frequencies. The digital computer completed this programme in 30 hours.

A comparison of the computed admittance values with all the available measurements showed that the assumed equivalent circuit for the point contact is valid over the entire frequency range from 2,000-18,000 Mc/s and that the spread in measured admittances can be accounted for by suitable variations in the values of R, r and C. This gave valuable information on the degree to which the magnitude of the various parameters must be controlled to produce crystals with uniform admittance characteristics.

Aerial Arrays of Maximum Directivity.

The reception of weak radio signals can be aided by the use of directive aerials which act on the incoming radio wave in a manner similar to that of a burning glass, collecting energy over a wide area and bringing it to a focus. Such directive aerials can also be used at the transmitting end (acting like the reflector of a searchlight), if the position of the receiving station is known. Only at very short wavelengths, however, is there any resemblance between the outward appearances of such directive aerials and their optical analogues. For short wave transmissions and for longer waves, the desired effect is obtained (still using the same basic principles) by so-called aerial arrays. These consist of a number of individual aerials, linked together by a feeder network in such a way that the

* This material is published by permission of the Admiralty.

currents in the individual aerials of the array stand in a certain amplitude and phase relationship to one another.

The directivity of such arrays is a subject of obvious practical importance. A recent investigation has been concerned with the precise condition to be fulfilled in order to make a given array radiate with maximum directivity. The study has shown that it is possible to specify this condition in a relatively simple way in the form of the "Travelling Wave Theorem".[3, 4] For arrays with identical elements, the Theorem states that with each element should be associated a voltage equal to that which would be produced at the element by a wave travelling in the direction in which the aerial is to "aim". Given this voltage for each element in the array, it is then possible to derive the element currents by means of an impedance matrix that contains only the real parts of the impedance matrix of the whole array.

The Theorem was originally derived by considering the signal strength that would be obtained at a distant receiving station in relation to the power consumed by the transmitting aerial array. This relationship has recently become more clearly understood by considering the aerial array in its receiving state.[5] If a certain well-known theorem, applying to two-terminal networks, is generalised to *n*-terminal networks, it becomes possible to specify the condition that must be fulfilled by the feeder network to the array. The *n* pairs of terminals of the feeder network must accept the same currents as would be accepted by a network that represented the complex conjugate of the network constituted by the aerials of the array.

Such a network can be constructed quite easily—at least on paper. When this is done, it is immediately seen that, when the receiving set is replaced by a transmitter, the distribution of aerial voltages and currents is that required by the Travelling Wave Theorem.

If an aerial absorbs maximum energy from the incoming wave, an amount equal to the amount absorbed is re-radiated from the aerial. It follows from the relations stated that such re-radiation takes place with maximum directivity in the direction in which the incident wave is travelling.

MATERIALS.

High Purity Metals.

The presence of small quantities of impurities in a metal or alloy can have a marked effect on its properties, both at normal and high temperatures, since the impurity atoms tend to segregate at specific points in the parent lattice, causing a modification of the deformation processes. One example of the effects of trace elements is the dependence of the ductility of the refractory metals chromium, molybdenum and tungsten, on the oxygen and nitrogen content. From both the practical and theoretical points of view, therefore, the preparation and examination of very high purity metals is of importance. Several purification techniques, which have recently been developed at the Research Laboratories, are being applied to a number of different metals ranging from copper and aluminium to molybdenum and tantalum.*

The zone-refining process, which has been used so successfully for semi-conductors, is also of considerable value for the purification of metals, although the segregation of specific trace elements in copper has shown that the efficiency of this technique is usually not as great as predicted by the simple mathematical theory. To apply the zone-refining process to high melting point metals, an apparatus has been developed for passing a molten zone along a vertical metal bar which is supported only at the ends, the zone being

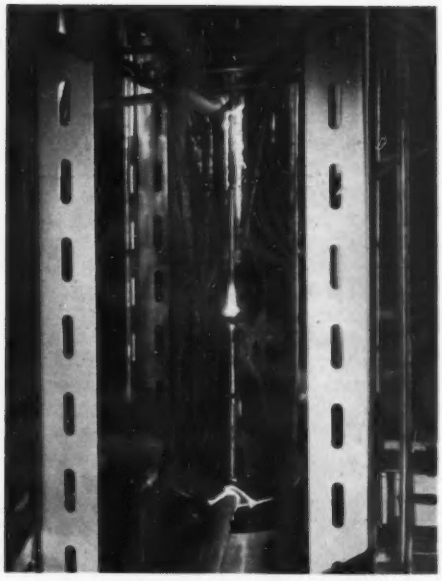


Fig. 3.—Apparatus for zone-refining high melting point metals.

held in position by surface tension forces (fig. 3). The molten zone is produced by a water-cooled copper coil connected to a high frequency generator, and the metal rod is moved slowly through the coil. The advantages of this "floating zone" technique are that the molten metal does not come into contact with any crucible material and that metals with very high melting points can be zone-refined.

Another purification technique applicable to high melting point metals consists of volatilising the impurities in an electric arc under a reduced pressure of argon or in a vacuum. This technique is carried out in a specially developed arc furnace in which a vacuum of 10^{-6} mm.Hg can be maintained. The furnace chamber is of glass and includes a gettering system so that, when an argon atmosphere is used, the gas can be continuously purified.

The removal of impurities by volatilisation can also

* Much of this work is being carried out in collaboration with the Culcheth Laboratories of the United Kingdom Atomic Energy Authority (Industrial Group).

Fig. 4.—Laboratory test equipment for heating refractory specimens in corrosive atmospheres.

be carried out on metals in the solid state. An apparatus has been designed for treating bars 8 in. long and up to $\frac{1}{8}$ in. square in a vacuum of 10^{-5}—10^{-6} mm.Hg. Bars of such metals as tungsten or tantalum can be maintained at a temperature just below their melting point, using direct resistance heating. A sensitive guide to the residual oxygen content of tantalum is its hardness, and the apparatus developed has enabled tantalum to be prepared with a lower hardness value than previously reported in this country.

The Attack of Superstructure Refractories by Batch Materials.

During recent years there has been a steady improvement in the quality of tank blocks for lining glass-melting furnaces, with the result that furnaces are now giving double the life achieved previously. The improvements have resulted from studies of the effect of molten glass on the refractory lining, but the development of refractories for the tank superstructure has tended to lag behind. It is now known that the gases above the glass surface also have corrosive and other deleterious effects on refractory materials. Indeed, the factor limiting the life of a furnace is often the failure of the superstructure refractories.

A laboratory equipment has been set up to test refractories under conditions similar to those encountered in the superstructure (fig. 4). Several refractory specimens are mounted in a special holder and lowered into an enclosure where they are heated in an atmosphere contaminated with dust and the vapours of various glass-making chemicals. After either 8 or 16 hours of this treatment at 1,400 deg. C., most refractories show severe corrosion (fig. 5). Further tests can then be carried out on the specimens to discover the exact cause of failure.

Results have shown that a very important factor in the corrosion results is the chemical relationship between the batch constituent and the refractory. The permeability and porosity of the specimens is also very important in some materials. Silica bricks of low permeability and low alumina content give greatly improved performance over the materials currently in use. In atmospheres contaminated with boric oxide vapour, zircon refractories are extremely resistant to attack, and zirconia mullite refractories have given good results with both boric oxide and sodium carbonate. While care is needed in selecting the right refractory for a particular application, great improvements in superstructure refractories are possible and there is no reason why satisfactory furnace life should not be obtained.

The Measurement of the Creep Rate of Graphite.

Graphite, now extensively used in the construction of nuclear power reactors, is almost unique in that its mechanical strength increases with rise of temperature. An investigation into the creep behaviour of graphite under constant stress at temperatures in the range 1,200 to 2,000 deg. C. is being carried out at the Research Laboratories. The graphite is tested in the form of a helical spring (fig. 8) mounted with its axis vertical in a vacuum graphite tube furnace.

The deformation is determined by recording photographically, at fixed intervals of time, the position of two reference bars attached to the specimen. A typical creep curve is shown in fig. 6. By using laboratory-made specimens it has been possible to study the wide variety of graphites which it is possible to prepare. Statistical analysis has shown that, for a wide range of

Fig. 5.—Six refractory specimens after being sprayed with borax for 8 hours at 1,400 deg. C. Left to Right: 50 per cent. alumina, 50 per cent. alumina (low permeability), 72 per cent. alumina, 44 per cent. alumina (medium permeability), sillimanite, silica.

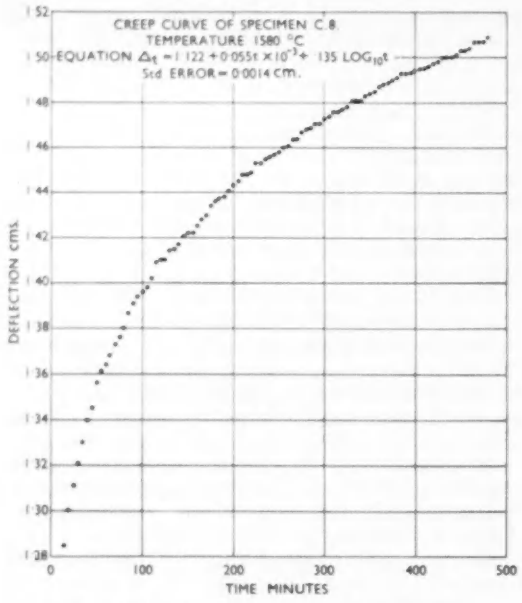


Fig. 6.—Creep curve of a specimen of graphite.

temperature and for the range of materials studied, the creep deformation conforms to the relationship:

$$\triangle = A + bt + k \log t$$

where $\triangle$ = deformation (cm.)

A = constant due to elastic constant

b = coefficient of steady state creep

k = coefficient of transient creep

t = time (measured in minutes).

For most experiments the standard error of curve fitting was 0·015 to 0·025 mm. The temperature coefficients of the constants have been interpreted in terms of activation energies for the mechanisms of strain relaxation at constant stress. These are independent of the gross grain-structure of the graphites investigated so far.

Fig. 8.—Helical spring of graphite used for investigating the creep behaviour of the material.

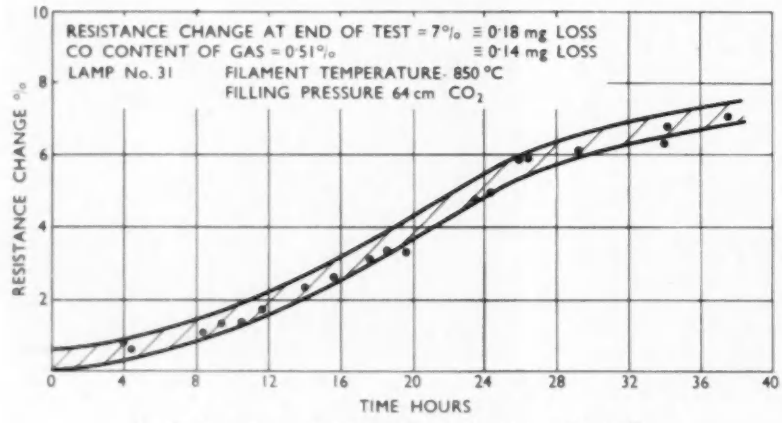


Fig. 7.—Typical control chart of electrical resistance of graphite.

A Simple Corrosion Test for Graphite.

The development of graphite as the moderator in gas-cooled nuclear reactors may be limited by purely thermal corrosion. For practical purposes it is necessary to consider corrosion rates smaller than a few per cent. weight loss in twenty years. These low corrosion rates can be measured either by very accurate determination of small changes over short periods of time or by less accurate measurements over longer periods. A simple method of achieving the latter is to test the specimen in the form of a filament such as is used in a carbon filament lamp. The reaction can be monitored by the measurement of the electrical resistance of the filament, and a more accurate determination

made at the end of the experiment by analysing the resultant gases in the lamp. The measurement of filament temperature can be simply carried out by infra-red photography.

The method used is to compare the image density obtained by photographing the filament on Kodak IRER plates with that obtained by photographing a

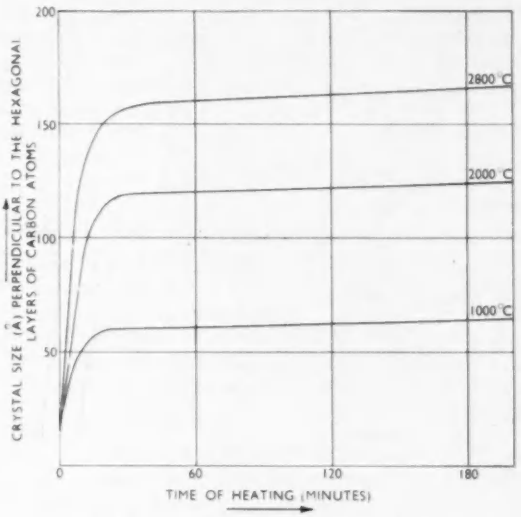


Fig. 9.—Crystal growth of a carbon black.

graphite block maintained at known temperatures in a tube furnace. This method will determine the temperature to an accuracy of ± 10 deg. C. directly and by calibrating each plate an accuracy of ± 3 deg. C. can be obtained. For example, it has been shown that, at 500 deg. C., filaments run in an atmosphere of carbon dioxide for nine months show no significant resistance change or carbon monoxide build-up, while those at higher temperatures show corresponding changes in both parameters. A typical control chart of electrical resistance is shown in fig. 7. This simple technique enables qualitative measurements to be carried out on a large number of specimens over a range of temperatures and with the minimum of apparatus.

X-RAY INVESTIGATIONS.

"Graphitisation" in Carbon Blacks.

Carbon is of growing interest in fields as diverse as atomic energy and rubber technology. A general problem, common to all these applications, concerns the development of the crystalline graphite structure from the amorphous material. It is well known that the "graphitisation" of carbon depends both on the constitution of the raw material and on the thermal treatment to which it is subjected.

Carbons have been broadly divided[6] into "graphitising" and "non-graphitising" carbons. Carbon blacks occupy a particularly interesting position in this classification and this is being studied by X-ray diffraction methods. Although carbon blacks contain a system of cross-linking which immobilises the structure (and is thus characteristic of non-graphitising carbons), some development of the graphitic structure can be achieved.

The present investigation includes a study of the response to various heat treatments of carbon blacks of different origins. Information is being obtained on, for example, the relative roles of temperature and time of treatment. By X-ray counter diffractometer technique, it has already been found that temperature is by far the more important of these two factors. Rapid "saturation" with time is clearly demonstrated in fig. 9, where crystal growth of a carbon black is shown as a function of time, for different temperatures.

Structure and Electroluminescence in Zinc Sulphide.

The true graphite structure is obtained when the positioning of successive layers of hexagonally arranged carbon atoms in the crystal structure is fully "ordered". Incomplete graphitisation means that the crystal structure remains, to some extent, disordered. A very similar process of ordering of layers of atoms occurs in zinc sulphide, a substance widely used as a phosphor. Here, change in ordering of atomic layers is responsible for the change from the cubic to the hexagonal form which occurs on heating to above approximately 1,000 deg. C. Recently it has been found[7] that a disorder process in the development of the crystal structure has special significance in relation to the electroluminescence which zinc sulphide can exhibit when suitably activated and excited. By starting with zinc sulphide in the hexagonal form and subsequently heating at a temperature in the region of 700 deg. C. with activator, it has been found that the volume electroluminescence which can then be stimulated by an electric field occurs at the boundaries between disordered regions in the crystal. Fig. 10 shows photographs of a crystal of zinc sulphide (a) electro-

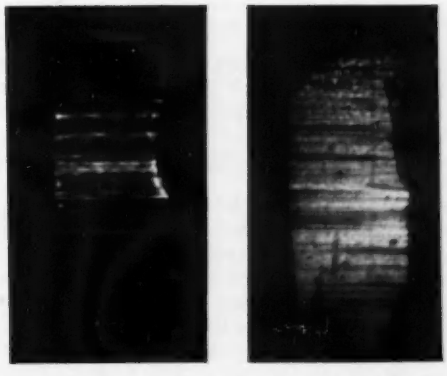


Fig. 10.—Electroluminescent crystal of zinc sulphide activated with copper: (a) electroluminescence under 10 kc/s. (b) in polarised light between crossed Nicols. (Magnification: 60X.)

luminescing and (b) in polarised light. It may be inferred from (b) and from X-ray diffraction analysis that the streaks of electroluminescence seen in (a) are parallel to disorder boundaries in the crystal structure. It thus appears that a disorder process plays an important part in the formation and constitution of this type of phosphor.[8]

A Device for Low-Temperature X-ray Examination.

Alterations in structure when crystals are heated or cooled through particular critical temperatures often accompany changes in magnetic dielectric properties, and so constitute an important field for study. Instruments must therefore be available which allow X-ray diffraction photographs to be taken while the specimen is held at a temperature either above or below room temperature. For a long while, commercial X-ray

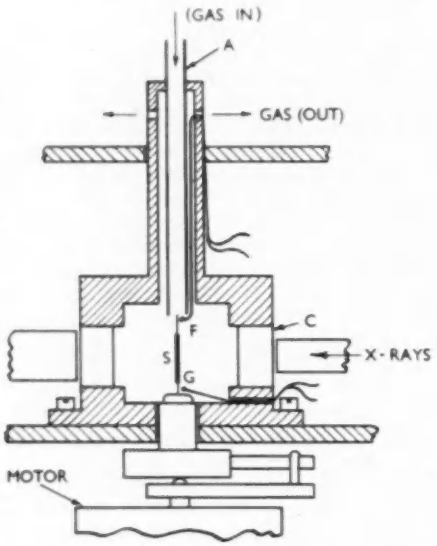


Fig. 11.—Section of cooling chamber for low-temperature X-ray diffraction analysis.

diffraction cameras have been in use for high-temperature work, but studies below room temperature have been limited to certain fixed low temperatures which can be obtained by streaming, say, liquid oxygen or nitrogen over the specimen while the photographic exposure is being made.

The limitation has now been overcome by the development of a technique in which the liquid coolant is replaced by a gas, usually oxygen or nitrogen. Either gas may be obtained by boiling its liquid with an electric immersion heater in a large Dewar flask. The evaporated product is led into the X-ray camera through metal cooling spirals immersed in liquid oxygen. By varying the rate of flow, or by mixing the cold gas with a stream of warm, dry gas from a nitrogen cylinder, any temperature between 20 deg. C. and −140 deg. C. can be obtained and held steady for several hours while the X-ray diffraction photograph is taken.

A sectional view of the arrangement (fig. 11) indicates how the specimen *S* is cooled by a jet of cold gas travelling down its length. A film base enclosure *C* surrounds the specimen and prevents cold gas from entering the camera space and thus cooling the X-ray film. Exit gas passes up through the annular space surrounding the brass inlet tube *A*. This provides an autogenous cooling effect which helps to reduce the consumption of coolant. Temperatures are measured with the thermocouples *F* and *G*. The pattern of diffraction X-rays, from which the crystal structure of the powder specimens is deduced, is recorded on a narrow cylindrical strip of film concentric with the specimen.

INSTRUMENTS AND TECHNIQUES.

An Aerodynamically-Operated Grit Separator.

The expansion and modernisation of the plant of United Lamp Black Works Ltd. has emphasised the need for new methods of handling and sifting the product. This takes the form of the lamp black which is used in rubber manufacture and is an exceedingly fine powder and thus easy to convey pneumatically. A method which separates foreign particles from the suspension of lamp black in air therefore saves handling of the product and is economically attractive. The method must, however, be 100 per cent. effective since an infinitesimally small percentage of unwanted inclusions would be sufficient to interfere drastically with the whole of the subsequent rubber-making process.

The problem of grit separation was therefore studied in the Research Laboratories, and a screen was devised which could be incorporated in the pneumatic conveyor without altering either the gas velocity or the pressure drop. Clogging of the screen was overcome by providing a suitable system of air jets which traversed the screen. Prototypes on a works scale have now been built and operated for about a year. It has been found possible to sift lamp black at the rate of 200 lb. per hour and to retain all the foreign particles rejected by a 76 mesh B.S. screen. Compressed air (at 60 p.s.i.g.) is consumed at a rate of about 6 free cu. ft. per lb. of lamp black. Careful tests on large (50 lb.) samples of the product have shown that the grit has been effectively removed.

The technique has applications in other industries where similar types of material have to be handled, and trials with various other finely powdered materials are now proceeding.

Photoelectric High-speed Recording Telepyrometer.

Studies of the factors affecting the quality of bulbs made on automatic bulb-blowing machines made it necessary to be able to measure the instantaneous temperature of the molten glass, both in the tank and on the blowing spindles. An experimental photoelectric high-speed recording telepyrometer (fig. 12) has been developed for this purpose which will record

the temperature of any selected small portion of the glass in 0·5 sec. to an accuracy of ± 1 deg. C. within the range 900 to 1,200 deg. C.

Any photoelectric apparatus in the immediate vicinity of a large glass furnace would be damaged by the intense radiation, and the pyrometer was therefore designed to operate about 12 ft. away from the surface of the glass to be measured. In order to collect sufficient radiation from chosen small areas of glass down to about 1 in. diameter, a telescope with 3 in. diameter objective was used to collect the light. In the image plane a small aperture in front of a photocell restricted the field of view to the required angular subtense of about 0·4 deg. The light so received is compared with that from a calibrated tungsten filament comparison lamp, adjusted in intensity so that the signal which it produces from the photocell is the same as that produced by a full radiator at a known temperature. This is achieved by means of a rotating sector mirror which alternately presents the two radiations to the photocell. Provision is made for adjusting the comparison source to one of several temperature-measuring scales which can be set appropriately to within 20 deg. C. of the temperature of the test source. Any remaining difference from the comparison source will give rise to an a.c. signal from the photocell. After suitable amplification and rectification, this signal operates a high speed pen recorder which indicates the instantaneous temperatures.

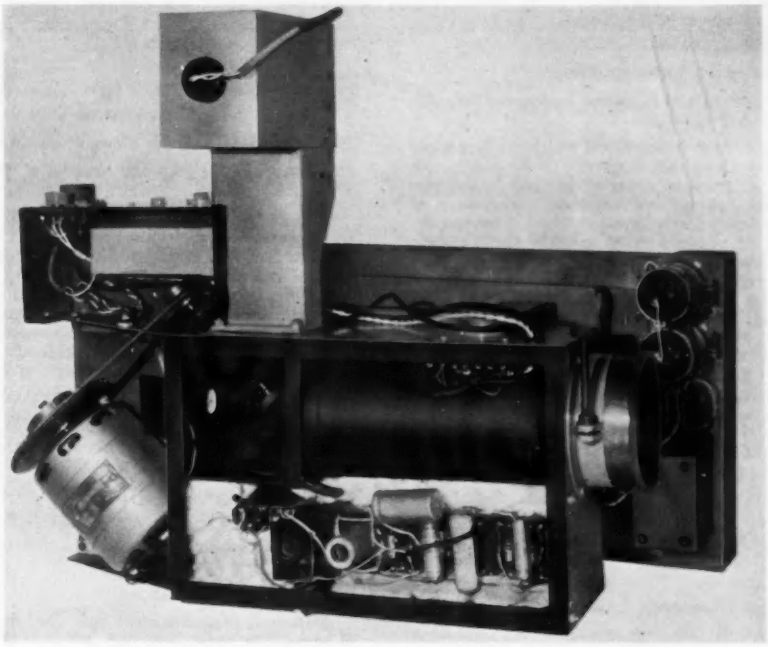


Fig. 12.—Receptor unit of the photoelectric high-speed recording telepyrometer.

REFERENCES.

1. H. M. Ferguson, J. Reeves, and W. R. Stevens, *G.E.C. Journal*, Vol. 20, No. 3, p. 184, 1953.
2. British Patent Application No. 8363/56.
3. A. Bloch, R. G. Medhurst, and S. D. Pool, *Proc. I.E.E.*, III, Vol. 100, p. 303, 1953.
4. British Patent No. 740698.
5. A. Bloch, *Wireless Engineer*, in course of publication.
6. R. Franklin, Proc. Roy. Soc., A., Vol. 209, p. 196, 1951.
7. M. A. Short, E. G. Steward, and T. B. Tomlinson, *Nature*, Vol. 177, p. 240, 1956.
8. A. H. McKeag, and E. G. Steward, *Jnl. Electrochem. Soc.*, in course of publication.

TECHNICAL LITERATURE

A digest of recent articles and papers by members of the G.E.C. and its associated companies

PULSE-TIME MODULATION TERMINALS FOR MUSIC TRANSMISSION OVER RADIO LINKS (601).*

By R. F. Rous (Research Laboratories).

Proceedings of the Institution of Electrical Engineers, Vol. 103, *Part B, No.* 9, *pp.* 283-294, 1956.

A communication system is described which enables three music circuits and an engineer's circuit to be combined. The combination is effected by using pulse time modulation in four time-division multiplexed channels. The purpose of the system is to enable a microwave link, intended for the transmission of television signals, to carry audio signals of broadcast-programme quality as an alternative. The radio equipment, primarily intended for television transmission, need not be specially designed for this particular service. The choice of time division as a multiplexing method is discussed, and the selection of the pulse repetition frequency, duration and time deviation is explained. A detailed description of the multiplexing circuit is given, and both the performance specification and actual measured performance figures are tabulated. Finally, the signal/noise ratio obtained with the radio link working over a 25-mile path is discussed, and the improvement which results from the use of pulse time modulation is explained.

R.F. BANDWIDTH OF FREQUENCY-DIVISION MULTIPLEX SYSTEMS USING FREQUENCY MODULATION (636).*

By R. G. Medhurst (Research Laboratories).

Proceedings of the I.R.E., Vol. 42, *pp.* 189-199, *February*, 1956.

The radio-frequency energy distribution of a Frequency-Division-Multiplex, Frequency-Modulated Multichannel telephony system is evaluated. An estimate is obtained of the inter-modulation noise generated when this spectrum is passed through an "ideal" bandpass filter with very sharp cut-off. From this it is possible to specify the minimum bandwidth of such a filter in terms of required system performance. This result provides a useful guide to the bandwidth over which control of group-delay and attenuation is necessary.

HIGH-TEMPERATURE STRUCTURE TRANSITIONS IN SODIUM NIOBATE (643).*

By M. H. Francombe (Research Laboratories).

Acta Crystallographica, Vol. 9, *pp.* 256-259, *March*, 1956.

A detailed X-ray 'powder' study of sodium niobate at high temperatures has confirmed the conclusion, reached from optical investigations on single crystals, that the crystal structure does not become strictly cubic until the temperature reaches 650 deg. C.

At temperatures between 420 deg. C. and 480 deg. C., the X-ray evidence is consistent with a slightly distorted multiple unit cell with a tetragonal axial ratio very near to 2. At temperatures above 480 deg. C. tetragonal-type diffraction line splitting reappears and the axial ratio increases to 2·0038 at 560 deg. C. This effect is accompanied by a reduction in the intensity of superlattice reflections. At 640 deg. C. both these reflections and the line splitting disappear, indicating a completely isotropic perovskite-type structure.

An explanation of the X-ray effects is suggested in terms of atomic displacements.

OBSERVATIONS ON THE GROWTH OF EXCESS CURRENT IN GERMANIUM P-N JUNCTIONS (653).*

By A. R. F. Plummer (Research Laboratories).

Proceedings of the Physical Society, B, Vol. 69, *pp.* 539-547, 1956.

The excess current induced in a germanium p-n junction by water vapour was found to be time dependent, and three separate relaxation times were observed. By taking the time of growth into account the excess current was resolved experimentally into two components having linear and saturation relationships with the applied voltage. The surface structure assumed to be responsible for the saturation component does not develop until after a reverse voltage has been applied to the junction, and when the applied voltage is removed this surface structure disappears rapidly compared with the time of growth.

The possibility that these components correspond to channel and surface leakage currents is discussed.

THE THERMAL CONDUCTIVITY OF BISMUTH TELLURIDE (654).*

By H. J. Goldsmid (Research Laboratories).

Proceedings of The Physical Society, B, Vol. 69, *pp.* 203-209, 1956.

Abstract. Measurements of the thermal conductivity of bismuth telluride have been made in the range of temperature 150 deg. K. to 300 deg. K. It has been found that the electronic contribution to the conduction of heat is considerably greater for specimens in which the charge carriers are intrinsically excited than for specimens in which most of the carriers arise from an impurity concentration; this can be explained by the recently proposed theory which takes into account the transfer of ionisation energy down a temperature gradient.

A NEW SODIUM LAMP (685).*

By E. H. Nelson and S. A. R. Rigden (Research Laboratories).

Light and Lighting, Vol. 49, *pp.* 217-20, *August*, 1956.

The processes in the discharge which give rise to problems in the design of a successful sodium lamp are reviewed, and the construction is described of a new integral lamp in which improved heat conservation results in a substantial increase in luminous efficiency compared with the Dewar-jacketed type. It is shown that not only is the starting voltage lower as a result of certain design features, but that it is likely to remain at a low level for a longer time. The highly-evacuated outer jacket which encloses the arc tube eliminates humidity effects which may cause an increase in starting voltage in the Dewar-jacketed lamp, and several other characteristics are reviewed which make the new design attractive to the street-lighting engineer.

*** A limited number of reprints is available of those papers marked with an asterisk. Copies may be obtained on application to the Editor, G.E.C. Journal, Magnet House, Kingsway, W.C.2.**